This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

**Usage guidelines**

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

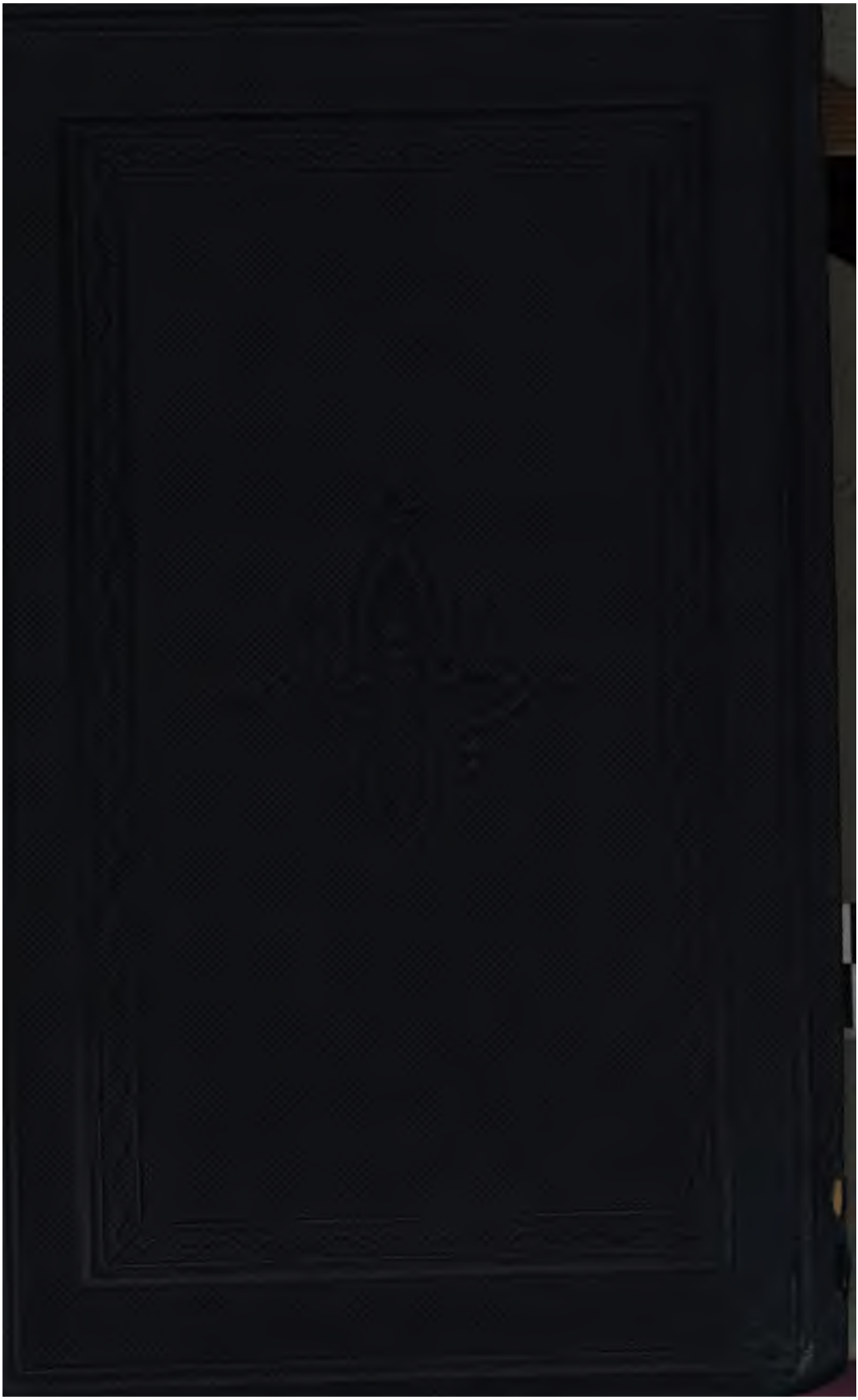
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

**About Google Book Search**

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`



Soc. 18611 e. 156/55

# MINUTES OF PROCEEDINGS

OF

# THE INSTITUTION

OF

# CIVIL ENGINEERS;

WITH OTHER

## SELECTED AND ABSTRACTED PAPERS.

## VOL. LV.

SESSION 1878-79.—PART I.

EDITED BY

JAMES FORREST, Assoc. Inst. C.E., Secretary.

LONDON:
Published by the Institution,
25, GREAT GEORGE STREET, WESTMINSTER, S.W.
1879.

[*The right of Publication and of Translation is reserved.*]

## ADVERTISEMENT.

THE Institution is not, as a body, responsible for the facts and opinions advanced in the following pages.

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, STAMFORD STREET AND CHARING CROSS.

# CONTENTS.

## SECT. I.—MINUTES OF PROCEEDINGS.

*November* 5, 1878.


PAGE

Special General Meeting . . . . . 1


*November* 12, 19, *and* 26, 1878.


"The Avonmouth Dock." By J. B. MACKENZIE (2 plates, 1 woodcut) . 3

"The River Lagan and Harbour of Belfast." By T. R. SALMOND (1 plate, 1 woodcut) . . . . . 22

"Whitehaven Harbour and Dock Works." By J. E. WILLIAMS (2 plates) . 36

Discussion on Harbour and Dock Works (6 woodcuts) . . . . . 49


*December* 2, 1878.


Special General Meeting . . . . . 121


*December* 3 *and* 10, 1878.


Election of Members . . . . . 124

Transfer of Associates to Class of Members . . . . . 124

Admission of Students . . . . . 124

"On the Heating and Ventilating Apparatus of the Glasgow University." By W. W. PHIPSON (1 plate) . . . . . 124

Appendix to ditto . . . . . 142

Discussion on Warming and Ventilation (4 woodcuts) . . . . . 144


*December* 17, 1878.


Annual General Meeting: Election of Council . . . . . 173

Annual Report . . . . . 175

Abstract of Receipts and Expenditure . . . . . 188

Premiums Awarded, Session 1877–78: Subjects for Papers, Session 1878–79 192

List of Original Communications, and of Donors to the Library, 1877–78 . 199

List of Officers . . . . . 206

## SECT. II.—OTHER SELECTED PAPERS.

PAGE

"The Eastern Canal of France; for Establishing a Line of Water-Communication from the Saône to the Meuse." By W. B. DAWSON (2 plates) 207

"Draining and Improving 1,500,000 acres of Desert Land." By G. WILSON 234

"On the Slopes of Cuttings." By W. AIRY (9 woodcuts) . . . . . 241

"The Chalk Water Supply of Yorkshire." By J. R. MORTIMER (1 plate) . 252

"Coal-Washing Apparatus at Bessèges, France. By J. B. MARSAUT. (Translated and abstracted by A. BACHE.) . . . . . 259

"On the Progress of Public-Works Engineering in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By L. F. VERNON-HARCOURT . . . . . 275

"On the Progress of Machinery in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By D. K. CLARK . . . . . 286

"On the Progress of Mining and Metallurgy in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By H. BAUERMAN . . . . . 297

"On Progress in the Application of Electrical Science to Engineering Purposes in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By PAGET HIGGS . . 308

Memoirs of Deceased Members . . . . . 315

William Baker, 315; Sir Richard Griffith, Bart. 317; James M'Nair Harkness, 318; Julian Horne Tolmé, 319; William Thorold, 321; John Thomas Woodhouse, 322; Henry William Ferdinand Bolckow, M.P., 325; John Boyd, 326; Charles Currey, 327; Thomas Barnabas Daft, 329; Charles Wilson Faber, 330; Henry Pooley, 331; Major George Swetenham, R.E., 334; Sir Frederick Martin Williams, Bart., M.P., 335.

## SECT. III.—ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

Regulations for the Uniform Supply and Testing of Portland Cement . . 336

Foundations in Sand on the coast of the Department du Nord. M. PLOCQ . 337

The nature of Soils, and Slips in Clay Soils. R. LEFEBVRE . . . . . 338

Determination of the Stresses permissible in Structures. J. SEEFEHLNER . 342

Thickness and Form of the Arches of Stone Bridges. G. TOLKMITT . . . 344

Strains produced in Arched Drawbridges by Wind-pressure. R. KOHFAHL. 345

Iron Bridge over the River Inn at Königswart. C. SCHNORR v. CAROLSFELD and A. ROTTMÜLLER . . . . . 347

Queen Carola Bridge over the Elbe, near Schandau. Hr. HOFMANN . . . 350

Substitution of a Single Span for Two Openings of the Magdeburg Railway Bridge. H. KÄFERSTEIN . . . . . 352

Securing Air-Lock Doors in Sinking by Compressed Air. A. HEINERCHEIDT 354

Roads, Streets, and Pavements in Victoria and Tasmania. C. T. HARGRAVE 355

Power of Running Water to Hold Matters in Suspension. J. P. FRIZELL . 356

PAGE
On the Cause of the Maximum Velocity of Water Flowing in Open Channels being Below the Surface. J. B. Francis. . . . . 357
Observations on the Level of the Elbe in Saxony. M. W. Schmidt . . . 358
Regulation of the Rhone in the Canton of Valais. Hr. Honsell . . . . 359
Regulation of the Rivers Brenta and Bacchiglione. G. Ponti . . . . 361
Torrents on the Coast of the Ionian Sea between Reggio and Assi. Chev. G. Amenduni . . . . . 364
Improvement of the St. John's River, Florida. J. B. Eads . . . . . 365
The South Pass Jetties, Mississippi River. E. L. Corthell . . . . . 367
Construction of the Narora Works, Lower Ganges Canal. Major H. H. Jones, R.E. . . . . 371
The Harbour Works at Flushing . . . . . 372
The Campana Graving Dock, Arsenal of Ferrol, Spain . . . . . 374
Lake Dam at Rappersweil, Zurich . . . . . 376
Excavators, &c., employed on the Danube Regulation Works and the Gand and Terneuzen Canal . . . . . 378
Experiments on the Flow of Air through Orifices in a Thin Plate. A. Fliegner . . . . . 379
The Flow of Water in Pipes under Pressure. C. G. Darrach . . . . 381
The Potsdam Waterworks. W. H. L. Green . . . . . 383
Water Supply of Boston, U.S. . . . . 385
Water Supply of Fall River, U.S. . . . . 386
The Quebec Waterworks . . . . . 387
Railway Across the Andes from Lima to Oroya . . . . . 387
Conditions for the Establishment of Secondary Railways. MM. Béral and de Basire . . . . . 388
On the Life of Rails. A. Funk . . . . . 391
Double-hook Couplings for Rolling Stock. A. Agthe . . . . . 393
Theory of the Action of Railway Brakes. E. Perron . . . . . 394
On Continuous Brakes. C. Schneider . . . . . 396
Self-Lubricating Hollow Axle for Mining Wagons, &c. J. Libert . . . 398
Fireless Locomotive for Tramways. M. Francq . . . . . 399
Slow Combustion under Pressure. J Henin . . . . . 399
Purification of Greasy Water by Solution of Lime. MM. Hétet and Risbec 400
Theory of the Injector. E. Hermann . . . . . 402
The Korting Injector as an Air-Blast. A. Scheurer-Kestner . . . . 403
Spur Fly-Wheels in the United States. J. F. Radinger . . . . . 404
Casting of Chilled Gearing for Roll Trains. E. Laduron . . . . . 405
On the Calculation of Pitch Chains. K. Keller . . . . . 406
Explosion of the Flouring Mills at Minneapolis, Minnesota. S. F. Peckham 407
On Testing Machines for Iron and Steel. R. Bredt . . . . . 408
Piccard's Apparatus for Evaporating Brine without Fuel. C. von Balzberg 409
Air-Compressors and Rock-Boring Machines. H. Mativa . . . . . 411
Könyves-Tóth Hand Rock-Drill. E. Wawra . . . . . 414
Iron Caisson at Grosstadeln, near Leipzig. C. W. Schulze . . . . . 414
Increased Rarefaction by Combination of Centrifugal Ventilators. J. Henin 418
Materials for the Study of the Bessemer Process. E. Chernoff . . . . 418
Researches on the German Bessemer Process. F. C. G. Müller . . . 419
Performance of Coke Furnaces under various Conditions of Draught . . . 422
Distillation of Petroleum Gas on the Scheuer System . . . . . 424

PAGE
Mineral Production of Austria in 1877 . . . . . 426
Mineral Production of Russia in 1876 . . . . . 427
Receiving Instrument for Submarine Lines . . . . . 428
Variations of Electric Currents transmitted through Imperfect Conductors. Count DU MONCEL . . . . . 428
Variation of Current under Modification of Pressure-Contact. M. TRÈVE . 429
New Form of Tangent-Galvanometer. E. OBACH . . . . . 429
Subdivided Electro-Magnet. P. GERMAIN . . . . . 430
Experimental Researches on Magneto-Electric Machines. MM. MASCART and ANGOT . . . . . 430
Motor for Electric Lamps. M. DE MERSANNE . . . . . 434
Baro-Electric Light Regulator. M. BOUTEILLOUX . . . . . 435
Application of the Telephone to Determining the Magnetic Meridian. H. DE PARVILLE . . . . . 435
A New Telephonic Transmitter. P. DUMONT . . . . . 436
On some New Effects produced in the Telephone. Count DU MONCEL . . 436
Physical Action of the Microphone. Count DU MONCEL . . . . . 437
The Sonorous Voltameter. T. A. EDISON . . . . . 438
Electrolysis of Cobalt. A. GAIFFE . . . . . 438
Solar Radiation. A. CROVA . . . . . 438
Radiation of Heat. Sr. VILLARI . . . . . 439
New Explosive. P. HESS . . . . . 439
Ventilation of the Transport 'Annamite.' L. E. BERTIN . . . . . 441
Blue Process for Copying Tracings. P. BARNES . . . . . 443

INDEX . . . . . 444

---

## ERRATA.

Vol. xlv., p. 270, line 27; p. 271, line 15; p. 272, heading of 5th column; p. 272, line 10 from bottom, for "six times the breaking weight" read "one-sixth the breaking weight."

Vol. liv., p. 165, „ 15 from bottom, for "50" read "150."

„ p. 166, „ 22 from bottom, for "the iron boilers, on many important points" read "the iron of the boilers and many other important points."

„ p. 167, „ 15, for "span in the boilers" read "space in the tubes."

„ „ „ 19 from bottom, for "50" read "55."

„ „ „ 14 from bottom, for "313·5" read "383·5."

„ p. 168, „ 20, for "$3\frac{1}{2}$ density" read "$\frac{1}{3\frac{1}{2}}$ density."

„ p. 195, first column, line 5 from bottom, for "21,150" read "2,110."

THE

# INSTITUTION

OF

# CIVIL ENGINEERS.

SESSION 1878-79.—PART I.

## SECT. I.—MINUTES OF PROCEEDINGS.

November 5, 1878.

## SPECIAL GENERAL MEETING.

J. F. BATEMAN, F.R.SS. L. & E., President, and subsequently W. H. BARLOW, F.R.S., Vice-President, in the Chair.

THE SECRETARY read the Summons convening the Meeting as follows:

"The Institution of Civil Engineers.

"25, GREAT GEORGE STREET, WESTMINSTER, S.W.

"*25th October*, 1878.

"The Council consider it expedient to propose the enactment of certain new Bye-Laws and Regulations, and the alteration and repeal of certain existing Bye-Laws and Regulations. A printed draft, showing such proposed enactments, repeals, and alterations, is sent herewith, as also a printed Statement of the general tenor and objects of the new Bye-Laws and Regulations, and of the proposed alterations and repeals.

"A General Meeting will be held at the house of the Institution on Tuesday, the Fifth of November, 1878, at 2.30 o'clock, in the afternoon, to decide on the same.

"At this Meeting all existing Members, Associates, and Honorary Members will be entitled to be present, to take part in the proceedings, and to vote.

"By Order,

"JAMES FORREST,

"*Secretary.*"

The Statement, and proposed new Bye-Laws which accompanied the Summons, were taken as read.

The PRESIDENT then explained the general purport of the pro-

posed new Bye-Laws, and concluded by moving that they be approved and adopted.

Mr. W. H. BARLOW, Vice-President, seconded the Resolution.

Upon which an amendment was moved by Mr. J. B. HUNTINGTON, Member; seconded by Mr. W. H. LUCAS, Associate:

> "That the Case which had been submitted to Counsel, with the opinion thereon, be read."

This amendment, on being put by the President, was declared to be lost.

The following amendment was then moved by Mr. G. BERKLEY, Member, and seconded by Mr. J. B. HUNTINGTON, Member:

> "That the words 'Senior Members (or Fellows) and' be omitted from Clause 1, Section II., and that the subsequent Bye-Laws be amended under legal advice to conform to this alteration."

After considerable discussion, the PRESIDENT put the amendment to the Meeting, which he declared to be carried by a majority of 126 against 94. The amendment was then put as a substantive Resolution, and was carried by a majority of 102 against 91.

The PRESIDENT then moved—

> "That the remainder of the Bye-Laws be adopted, subject to such alterations as may be necessary, under legal advice, to carry out the previous decision of the Meeting."

This motion was seconded by Mr. ABERNETHY, Vice-President. Whereupon an amendment was moved by Mr. VALENTINE G. BELL, Member, seconded by Mr. MAIR, Member:

> "That the existing Bye-Laws of the Institution be adopted by this Meeting with such modifications as Counsel may advise may be required to put them in conformity with the Charter."

The PRESIDENT having retired, the Chair was taken by Mr. BARLOW, Vice-President.

After discussion, a further amendment was moved by Mr. W. B. LEWIS, Member, seconded by Mr. R. PRICE WILLIAMS, Member, as follows:

> "That the Bye-Laws as submitted to the Meeting by the Council, and amended by Mr. BERKLEY's Resolution, be remitted to the Council for further consideration."

The first amendment having been withdrawn, the amendment proposed by Mr. LEWIS was, after considerable discussion, agreed to, and the proceedings terminated.

(Signed) J. F. BATEMAN.
W. H. BARLOW.

November 12, 1878.

JOHN FREDERIC BATEMAN, F.R.SS. L. and E., President, in the Chair.

No 1,547.—"The Avonmouth Dock." By JOHN BOWER MACKENZIE, M. Inst. C.E.[1]

BRISTOL is mentioned at an early period of history as one of the chief shipping ports in the kingdom. Down to the era of ocean steamers, it was accounted only second in importance to the port of London. At the commencement of that era, Bristol lost her leading position, and declined to a comparatively subordinate rank. Ocean steamers required ocean docks. Bristol failed to adapt herself to the new circumstances, and the trade which naturally belonged to her was attracted to other ports. Had the docks, which it is the object of this Paper to describe, been provided forty years ago, there is little doubt that she would have continued to occupy a position not inferior to that which she had held for many centuries.

As early as 1765, Smeaton submitted a scheme for a floating dock; but until 1808 the port had only a tidal harbour, the ships grounding on the mud at low water. About that date William Jessop, a former pupil of Smeaton's, carried out an extensive scheme of harbour improvements. Among others, a length of 2½ miles of the river Avon, which flowed through the heart of the city, and which had hitherto served as the tidal harbour, was converted into a floating dock, giving a water space of 82 acres; an entrance basin and two locks were constructed, and a new course for the river Avon was cut, at a total cost of about £600,000. These improvements gave Bristol ample dock accommodation for many years, and it was not until large steamers began to be used that any inconvenience was felt with the existing arrangements.

Bristol had the merit of initiating ocean steam navigation. In June 1837, the "Great Western," the first large steamer that crossed the Atlantic, sailed from Bristol. The "Great Britain," a much larger one, also built in Bristol, sailed from thence in 1843. But these and other large ships had to contend with

[1] The discussion upon this Paper was taken in connection with that upon the two succeeding Papers, and occupied portions of two evenings.

serious drawbacks in trading with the port. If they happened to arrive during neap tides, they had to remain at anchor in the roadstead, at the mouth of the Avon, waiting for spring tides to give a sufficient depth of water in the approach to the docks. There was also the risk of navigating the narrow and tortuous course of the river Avon from the Bristol Channel to the city, a risk which received a forcible illustration in the stranding of the "Demerara," a large steamer, on her first passage down the river in 1854. This state of things, and the growing tendency to employ large steamers for foreign trade, drew attention more and more to the question of dock accommodation. A great variety of schemes had already been proposed for constructing piers and docks at the mouth of the Avon and at Portishead. Indeed, for a period of thirty years (1828–1858) engineers were constantly submitting plans and reports; but the city authorities were invariably divided in opinion respecting them, and no steps were taken to carry any of them into effect. Among the schemes proposed, the following are worthy of mention:

In 1828, a masonry pier at Portishead, by W. C. Mylne, M. Inst. C.E.

In 1839, the construction of docks, "some distance down the Avon," and a floating pier at Portishead, by I. K. Brunel, M. Inst. C.E.

In 1841, a breakwater pier at Portishead, by Sir John Macneill, M. Inst. C.E.

In 1852, an ocean steam packet station at the mouth of the Avon, by J. M. Rendel, President Inst. C.E., assisted by W. W. Patterson, of Bristol, and George Thornton, engineer of Hull Docks.

From 1833–58, various designs for piers and docks, and one for "dockizing" the river Avon, by Mr. Thornton.

In 1858, plan for "dockizing" the river, by Thomas Howard, M. Inst. C.E., engineer of the Bristol Docks.

In October 1859, the Town Council submitted sixteen of the schemes proposed to Mr. T. Page, M. Inst. C.E., and Mr. (now Sir John) Hawkshaw, Past President Inst. C.E., with an instruction to report "whether the plan for converting the river Avon into a floating harbour would be practicable, and generally as to the advantage of the scheme suggested; and if neither, what scheme in their opinion would be best for securing to Bristol her fair share of the ocean steamer trade of the country." These gentlemen presented their reports in July 1860. Both of them discouraged the notion of "dockizing" the river, chiefly on the ground

that the abstraction of the tidal water of the Avon might prejudicially affect the deep water of the anchorage at its mouth. They recommended instead the construction of a steam dock at the mouth of the Avon, a railway connecting the dock with Bristol, on the margin of the river, and the improvement of the river Avon. The Council, however, could not yet agree upon what should be done. These reports served but to intensify the differences of opinion existing on the subject. They were followed by six years of incessant debate and agitation, or, as it was locally designated, "the battle of the docks." The ultimate decision of the Town Council was to carry out an improvement of the existing docks, leaving the project of an ocean dock in abeyance. The scheme, however, was taken up by a private company, soon after this decision was arrived at. The directors of this company, since known as "The Bristol Port and Channel Dock Company," instructed Mr. James Brunlees, M. Inst. C.E., to report on the construction of a dock of the kind described in the reports of Messrs. Page and Hawkshaw. The result was that the directors adopted the scheme recommended by Mr. Brunlees, and in 1864 an Act of Parliament was obtained empowering the company to carry it into effect. This scheme, with slight modifications, is the one which, after long delay, and in spite of formidable difficulties, both financial and engineering, has at length been completed. The first sod was cut on the 26th of August, 1868, and the dock was opened for traffic on the 24th of February, 1877. The difficulties which the company had to contend with in raising the large capital necessary for the undertaking mainly account for the execution of the work having been spread over so long a period.

It is now proposed to describe more minutely the works referred to. The general plan of the dock is shown on Plate 1, Fig. 1. It is situated on the east or Gloucestershire side of the Avon, and so near its mouth that, from the anchorage of Kingroad in the Bristol Channel to the entrance lock, the distance is only about 1,000 yards. The lock was originally placed in the direct line, or fairway, of the Swash Channel, leading into the roadstead, and so that as much of the entrance as possible was brought within the scour of the Avon. This position is now somewhat altered; the set of the ebb tides during the last few years showing a tendency to deflect the course of the river towards the eastern side; a tendency which may ultimately require some training work to ensure the maintenance of a straight approach.

The entrance channel from the Avon to the lock is about 350 yards in length, by an average width of 70 yards; with a

depth at high water of equinoctial spring tides of 44 feet, and of 40 feet at ordinary spring tides.

The levels of the various tides, in reference to the sills, &c., are shown on Plate 1, Fig. 2. The dock is 1,400 feet in length and 500 feet in width, giving a water area of about 16 acres, and a length of quay wall of 3,200 feet. The south end is not protected by a wall, but is finished off with a slope of 2½ to 1, to allow for future extension.

## Tides.

As an illustration of the remarkable range of the tides and their rapid rise and fall, the observations of an equinoctial spring tide, taken at Avonmouth on the 8th of April, 1875, are given in Plate 1, Fig. 2. The total rise of this tide from low to high water was 43 feet 9¾ inches; the time occupied was five hours and nine minutes, while the greatest rise was during the third hour of flood, and was as much as 12 feet 4¼ inches. The total fall, on the other hand, was 43 feet 4¾ inches, occupying seven hours forty-two minutes, and the greatest fall was during the second hour of ebb, being 9 feet 3 inches. The diagram also shows an equinoctial neap tide observed on the 29th of April, 1875, which rose 17 feet 6¾ inches in six hours twenty-one minutes, and fell 16 feet 2½ inches in six hours. The difference of range between these tides is 26 feet 3 inches; and whereas the flood of an equinoctial spring tide is two hours shorter in duration than the ebb, the neap tide reverses this order, and takes twenty-one minutes longer in flowing than in ebbing. The range of an ordinary spring tide is 39 feet, or 5 feet less than the equinoctial; the range of an ordinary neap tide is 19 feet, or 1 foot 6 inches greater than the equinoctial. Fig. 2 also shows the levels of all these tides with reference to the sills of the lock and with other points.

A specially interesting and important feature of these tides is the quantity of mud which the water holds in suspension. The tide-water at Avonmouth is the muddiest in the Bristol Channel, and, with the exception of that of the Humber, is probably the muddiest in the kingdom. The complete silting-up of the old entrance of the Avon, called the "North Channel," a few years ago, and the opening up of the present "Swash Way," was a remarkable occurrence, and one which has been attributed to a variety of causes. It is only referred to here as a striking example of mud settlement and accumulation. The silting-up seems to have begun in 1865, when there was a depth in the channel of from 6 to 10 feet at low water of spring tides, although up to

1867 it had not made much progress; about the latter date, however, the silting-up became extremely rapid. The following is a list of measurements taken during the year when the rate of silting-up was most rapid:

MEASUREMENTS of SILTING-UP in NORTH CHANNEL TAKEN at MIDDLE DOLPHIN of PONTOONS.

| Date. | Depth. | Depth silted up. |
|---|---|---|
| | Feet. Ins. | Feet. Ins. |
| February 1868 . . . . | 24 3 | |
| | | 1 6 |
| March „ . . . . | 22 9 | |
| | | 2 1 |
| April „ . . . . | 20 8 | |
| | | 1 11 |
| May „ . . . . | 18 9 | |
| | | 2 1 |
| June „ . . . . | 16 8 | |
| | | 1 10 |
| July „ . . . . | 14 10 | |
| | | 1 6 |
| August „ . . . . | 13 4 | |
| | | 0 9 |
| September „ . . . . | 12 7 | |
| | | 1 4 |
| October „ . . . . | 11 3 | |
| | | 0 5 |
| November „ . . . . | 10 10 | |
| | | 1 8 |
| March 1869 . . . . | 9 2 | |
| Total . . . . . | | 15 1 |

This shows an average rate of accumulation of mud during twelve months of 1 foot 3 inches per month. The total length of the channel silted up was about 1,000 yards, and the total depth of water about 41 feet. There is still a depth of about 6 feet of water in the channel at high water of spring tides; and the accumulation of mud during the last few years has been hardly appreciable.

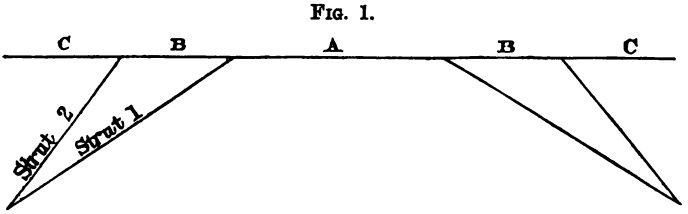
### TEMPORARY DAMS.

A temporary embankment was formed to exclude the tide during the construction of the works by tipping silt excavated from the dock over the ground. In order to consolidate the latter, stones were thrown out of barges, and piling and other timber work were used. The bank was raised several times before it finally came to a state of rest. The top was left 1 foot 6 inches above high water of equinoctial spring tides, and the side facing the tide was pitched roughly with stones and covered with brushwood. It became ultimately very hard and solid, and needed

but slight repairs during the progress of the work. The dam used to exclude the tide while the outer clay dam was being removed is shown in Plate 1, Figs. 3, 4, and 5. It is a wooden truss of simple and inexpensive character. It was built across the mouth of the lock; a recess or chase, suitable for fixing a permanent ladder in afterwards, being carried up the side walls for receiving the ends of the struts. The ends of some of the cross timbers were let into holes in the masonry, and the dam was bolted at the bottom to a transverse row of piles, driven to a depth of 18 feet into the sand below the foundations. The strength of the various members of the truss is shown in the following table, with a diagram of the strains (Fig. 1). The safe compres-

| | Part A. | | | Part B. | | | Part C. | | | Strut 1. | | | Strut 2. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total Load. | Breaking Weight of Material. | Factor of Safety. | Load. | Breaking Weight. | Factor of Safety. | Load. | Breaking Weight. | Factor of Safety. | Compression. | Area. | Load per Inch. | Compression. | Area. | Load per Inch. |
| | Tons. | | | Tons. | | | Tons. | | | Cwt. | Ins. | | Cwt. | Ins. | |
| 1 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 2 | 59·85 | 282·0 | 4·7 | 28·5 | 393·7 | 13·8 | 31·35 | 196·9 | 6·2 | 1,356 | 381 | 3·6 | 632 | 344 | 1·8 |
| 3 | 59·64 | 297·0 | 4·9 | 28·4 | 415·9 | 14·6 | 31·24 | 189·0 | 6·0 | 1,380 | 410 | 3·4 | 686 | 315 | 2·2 |
| 4 | 59·43 | 282·6 | 4·7 | 28·3 | 393·6 | 13·9 | 33·96 | 164·6 | 4·8 | 1,404 | 417 | 3·4 | 722 | 318 | 2·3 |
| 5 | 54·60 | 282·6 | 5·2 | 26·0 | 393·6 | 15·1 | 33·80 | 151·4 | 4·5 | 1,316 | 422 | 3·1 | 718 | 299 | 2·4 |
| 6 | 71·61 | 423·9 | 5·9 | 34·1 | 590·5 | 17·3 | 44·33 | 227·1 | 5·1 | 1,760 | 613 | 2·9 | 982 | 451 | 2·2 |
| 7 | 50·19 | 316·2 | 6·3 | 23·9 | 438·8 | 18·3 | 34·65 | 151·4 | 4·4 | 1,258 | 469 | 2·7 | 682 | 318 | 2·1 |
| 8 | 35·91 | 313·8 | 8·7 | 17·1 | 439·0 | 25·1 | 25·15 | 146·4 | 5·8 | 884 | 441 | 2·0 | 492 | 306 | 1·6 |
| 9 | 21·00 | 282·6 | 13·4 | 10·0 | 393·6 | 39·3 | 15·50 | 127·0 | 8·2 | 584 | 446 | 1·3 | 300 | 312 | 1·0 |

FIG. 1.




sion of the timber, the whole of which was of Danzig fir, is taken at 4 cwt. per square inch. The head of pressure upon it at high

water ordinary spring tides was 44 feet. The dam proved satisfactory in every way; and the leakage from the tide was so slight that a small force pump, raising the water 50 feet, easily got rid of it, together with all the other drainage water of the lock. So little iron work was used in framing the trusses, that the whole of the timber was fit for permanent purposes after the dam was removed.

Lock (Plate 2, Figs. 1, 2, 3, 4, and 5).

The mouth of the lock has a wing wall on each side, extending about 150 feet beyond the roundheads, and diverging from a line parallel with, and 100 feet distant from, the centre line of the lock at an angle of 11° 30′. The walls are of rubble masonry, faced with rough ashlar. They are 49 feet in height from the top of the footings to the coping, 23 feet 6 inches wide at the base, and 7 feet wide at the top. The face is battered to a radius of 150 feet, and the back has two steps 18 inches and two 12 inches wide. The footings are also of rubble masonry, 23 feet 6 inches wide, and 6 feet deep, and rest on the same bed of sand, and at the same level, as that on which the lock foundations are laid. The length of the lock between the return walls at each end is 600 feet. The masonry of the foundations varies from 100 to 120 feet in width, and from 5 to 6 feet in depth. On this bed of masonry the walls and inverts are built. The walls are of rubble, faced with random coursed ashlar. They have a batter of 6 feet 3 inches from the coping to the skewback of the invert, and a height of 47 feet 5 inches, the batter being curved to a radius of 157 feet. The inverts are of brick, 3 feet thick; the radius to which they are formed is 105 feet 4 inches, and the depth from the chord-line is 4 feet. The clear length between the inner and outer gates is 454 feet. This length is divided by a middle pair of gates into two locks, the inner one being about 50 feet longer than the outer one. The lower sills are placed 2 feet 7 inches above low water of equinoctial spring tides. The upper sill has a lift of 8 feet 3 inches above the lower ones, and the top of it is 1 foot 9 inches above the dock floor. The sluiceways for levelling and scouring are formed in the interior of the side walls. They are 7 feet wide by 4 feet 6 inches high, and have stone sides, with inverts and arches of brick in cement. They run parallel with the line of the walls, and their outlets within the locks are placed 50 feet from the hollow quoins. They have each seven inlets, opening in the recesses behind the gates, 2 feet 4 inches wide by 1 foot 9 inches deep, and consisting of

granite cutwaters and lintels. Each of the sluiceways is furnished with a strong cast-iron penstock and frame, fitted with brass faces. The upper sluiceways have also a pair of wooden paddles, for the purpose of allowing repairs to the iron penstocks.

The foundations of the lock rest upon a bed of fine grey sand underlying the clay at an almost uniform level throughout its length, and at a depth of about 6 feet under low water of equinoctial spring tides, or about the level of the present bed of the Avon near the dock. To what depth this bed of sand extends has not been ascertained, the trial borings not reaching deeper than 16 feet under low water of equinoctial spring tides; but piles have been driven to 9 feet below the level of the borings, and as far as pile driving can be relied on as indicating the nature of substrata, there appeared to be no change down to that depth. The frequent occurrence of springs in this sand was a source of some trouble and difficulty; most of them were weak, though two or three discharged a considerable volume of water. But whether weak or strong, they never appeared until the last layer of clay was removed, and the sand laid bare; a layer of clay 6 inches thick was sufficient to keep them down, but when this was once removed or disturbed, the springs burst out, and though the smaller ones were stopped after some weight of masonry had been placed on them, it was impossible to overcome the strong ones, and they had to be provided with permanent outlets. One of the strongest occurred in laying the foundations of the outer roundhead on the west side, which for a long time persisted in coming up at the same spot, in spite of every effort to shift it to a less dangerous place. After the wall had been built, it continued to wash up a little sand at the toe of the footings, producing large cracks in the masonry and causing the whole of the roundhead to settle downwards about 3 inches. The cracks were filled up with cement grout. Ultimately the spring was forced into another outlet and further movement of the wall stopped.

The apron in front of the lock at the outer end extends 60 feet beyond the outer inverts, and is 120 feet in width. It consists of a mass of lime concrete, mixed with blocks of stone of 2 to 3 tons weight, surrounded by walls of Portland cement concrete, 5 feet in thickness, and founded at a depth of from 8 to 10 feet below low water of equinoctial spring tides, or about 2 feet lower than the hearting. The top was pitched with heavy stonework, rough-faced, but dressed on the joints, and bedded in lias lime mortar. In founding this apron, more springs were met with; to

counteract which in some places wooden shoots, about 12 inches square, and funnel-shaped at the bottom, were placed vertically over them, and horizontal shoots of the same kind were laid through the concrete to take the water to the pumps. When the work was finished, the shoots were filled up by pouring cement grout into them. To ensure this being thoroughly done, a wrought-iron pipe, 2 inches in diameter, and about 50 feet long, reaching from the top of the lock walls to the apron, was inserted in the upright shoots, and the grout poured through it. By this means all the springs were forced into one outlet, which was made of a cast-iron pipe, fitted with a valve on the top, so that the spring water might have relief when the pressure of the tide was not counteracting it. A large quantity of water continued to escape at low water from this outlet up to the time of removing the timber dam, and the lock became full of water. Since then, however, it has burst up behind the row of piles in front of the outer invert, and has brought up a quantity of sand from the bottom between the piles and the masonry. This joint was caulked with rope, and the spring stopped, but it has still to be carefully watched, and although much weakened, it occasionally appears at different places on the apron.

The only other disturbance in the masonry of the lock was the rising of the outer platform about 3 inches after the roller paths were fixed and ready for the gates. The rising began shortly after the wooden dam across the lock was subject to the pressure of the tides. This pressure, forcing back the spring just referred to, and the slight settlements of the masonry of the gate recesses which had occurred, were sufficient to account for the movement. The roller paths were taken up and relaid, and the utmost exertion was made to finish the gates, so as to let the water into the lock and prevent further rising. Within three weeks of the relaying of the paths the water was admitted, but during this time the platform had not only further risen, but had begun to crack at various places, and to show by other symptoms that a dangerous movement was going on. The admission of the water, however, made everything safe, and the roller paths have slowly sunk to their former levels.

### Lock Gates (Plate 2, Figs. 6, 7, and 8).

The gates were originally designed of wrought iron with cast-iron heel-posts; but the high price of iron in the beginning of 1873, when the contract for the gates was settled, led to the adoption of

timber. The gates consist of oak heel and mitre posts, except in the case of the outer pair of gates, which are of greenheart, with ribs, intermediate posts, and walings of pitch pine and Memel. They are 2 feet 8 inches thick at the heel and mitre posts, and about 2 feet 11 inches at the centre of the leaf, exclusive of walings. The back of the gates, when shut, forms, from one hollow quoin to another, a continuous arc of a circle, the radius of which is 50 feet. The ribs and intermediate posts of the upper gates are differently arranged to those of the middle and outer gates. The three layers of cross pieces, of which the thickness of the gate is made up, are all cut to the same radius, and are divided into lengths or segments, the ends of which overlap or break joint with each other, and meet in a vertical post 12 inches square. The objection to this arrangement was, that nearly all the segments required an 18-inch balk of timber to cut them to the proper curvature, involving a waste of about 50 per cent. To reduce this waste, and to retain the same curvature and thickness of gate, the design shown in Figs. 6, 7, and 8 was adopted for the middle and outer gates. A similar arrangement of cross pieces and intermediate posts has been carried out in some dock gates at Liverpool. In this design the back of the ribs is the only curved face that has to be cut, all the other joints or faces being straight, involving scarcely any waste of timber. The ends of the rib segments do not break joint as in the upper gates, but meet in an intermediate post composed of six vertical pieces strongly built together. The whole of this system of ribs and posts is thoroughly braced and tied by wrought-iron straps and bolts and timber walings. The strength of these gates is calculated on the well-known principle that, in a gate of a circular or cylindrical form, at every point in the curve the pressure is equal, and its direction tangential to the curve of the gate. From this principle is deduced the formula $p\ r$, from which the stress on any cross section of the gate can be ascertained, $p$ representing the intensity of water pressure per unit of surface, and $r$ the radius of the gate. Applying this formula to a cross section of the gate 1 foot deep, and taking the head of water, for the sake of safety, at 45 feet, and $r$ as the radius of maximum pressure, or the greatest radius between bearing-points, at 60 feet, there is a total compression on this section equal to $64 \times 45 \times 60 = 172{,}800$ lbs. or 77 tons. The area of this cross section is 12 inches by 32 inches, equal to 384 square inches, or, making allowance for bearings of planking and defects of timber, say 350 square inches. The resistance of pitch pine or Memel fir to com-

pression is about 6,000 lbs. per square inch; but as timber is not nearly so strong when wet as when dry, and sometimes only half the strength, it has been taken in this case at $1\frac{1}{4}$ ton per square inch. The resistance of the whole cross section to strain is therefore—

$$350 \times 1\tfrac{1}{4} = 437\tfrac{1}{2} \text{ tons}$$

and

$$\frac{437\frac{1}{2}}{77} = 5{\cdot}7$$

As the ribs and spaces between them are so arranged that the stress on any cross section 1 foot deep does not exceed 77 tons, the gate has a minimum factor of safety of 5·7. The total weight of one leaf of the lower gates is 102 tons, of which 81 tons are of wood and 21 tons of iron. The weight of the greenheart heel posts was about 10·3 tons each, the greenheart weighing 76 lbs. per cubic foot. The timber work of the gates was prepared and fitted under a gantry upon the works. It was then taken to pieces, conveyed to the lock, and built in place with travelling cranes and 30-ton hydraulic jacks. Notwithstanding the great weights that had to be dealt with occasionally, the erection of the gates was accomplished without accident. A difficulty, however, occurred when they were nearly finished. It was found when a gate was moved on its roller that it did not stand plumb, but hung forward to the extent of 14 inches. The true position of the roller, the axle of which ought to be placed upon the line which passes through the centre of the heelpost and the centre of gravity of the gate, is difficult to determine with accuracy, when the gate is composed, as in this case, of materials of varying specific gravity irregularly distributed. It would have been impossible to have obtained a good mitre joint with so much deviation from the perpendicular as 14 inches, and it was therefore essential to remedy the defect. After considering various plans, it was decided to fix a small roller under the mitre post, and to lay down an additional roller path on the platform. The small roller was not made adjustable, the chief object being to keep the gates perpendicular while they were being mitred, and as the effect of wear and tear would be to lessen the weight on it and increase the weight on the large rollers. The plan was successful, and enabled a perfect mitre joint to be made. The gates have worked since with perfect ease, and are remarkably watertight.

Dock Walls (Plate 1, Figs. 6, 7, 8, and 9).

The height of the wall, from the dock floor to the coping, is 40 feet, and the depth of foundations below the dock floor varies from 2 feet 6 inches to 19 feet. The wall was commenced on the west side, and was at first built in open cutting, the ground behind being stepped back at various angles according to the nature of the soil. The foundations were laid in a bed of stiff blue clay, 2 feet 6 inches below the intended bottom of the dock. There was a bed of hard sand underlying the alluvial deposit at varying depths; but as the clay was a good strong material at the level referred to, it was not deemed necessary to go deeper. The form of cross section to which the first portion of the wall was built is shown in Fig. 6. The face has a straight batter of 1 inch to the foot, and the back has three off-sets, one 24 inches wide, and two 12 inches wide each. The footings are of lime concrète, 22 feet 6 inches in width, and are carried up 2 feet above the dock floor. From this level to the top, the wall is built of rubble masonry, faced with dressed stone, having, however, pockets in the interior filled with lime concrete. These pockets are 7 feet 6 inches long, by 5 feet wide, and are separated by rubble walls 2 feet 6 inches thick. The width of the wall at the base, 2 feet above the dock floor, is 16 feet, and the width at the top is 10 feet 6 inches.

When about 247 lineal yards of this section of wall had been built up to the level of the coping, and the backing was well advanced, a failure of about 90 yards occurred. Plate 1, Fig. 10, shows a plan of the portion of the wall affected by the failure. At the extreme point or apex of the slip, where the wall was broken through from top to bottom, it had slid forward 12 feet 6 inches, and sunk 4 feet 6 inches. The face showed cracks at various places, and many of the face stones were crushed. The dock floor was thrown up in front of the slip, and the ground broke away behind at an angle of 38° 30′, or at a slope of about $1\frac{1}{4}$ to 1.

Before proceeding farther with the wall, trial pits were sunk to ascertain the nature of the strata underlying the foundations. The result was that a mixture of clay and sand, nearly as soft as silt, was found between the clay upon which the footings were placed and the sand already mentioned, along the whole of the slipped portion of the wall, overlying the bed of hard sand for a depth of several feet. The sand occurred at an unusully low level, and at one point dipped as much as 19 feet below the level of the dock floor, where it was mixed with pebbles and shells. These results, it was thought, indicated the probability that the founda-

tion of the wall had crossed the bed of an old watercourse, or "pill," as it is locally termed, and subsequent observations of the ground, on relaying the foundations, confirmed the opinion.

The wall where not affected by the failure showed no tendency to slide out of place, but an inclination to overturn by coming forward at the top. It was built with a batter of about 3 feet 4 inches from the dock floor to the coping; but when the forward movement had ceased, the batter measured only 1 foot 8 inches. It thus stood about seven years, nearly fully backed up, with no support in front and without any further symptoms of movement. On the other hand, the portion of the wall that failed measured its full batter after the slip took place.

From the experience gained by the accident, it was decided for the future not to trust the foundations on the clay, but in all cases to go down to the bed of sand, filling up the excavated trench with lime concrete. A change was also made in the section of the wall, and the profile shown in Plate 1, Fig. 7, was adopted. In this case the face of the wall has a circular batter, the radius being 150 feet. The width of the footings is 22 feet 6 inches. The base of the wall, 2 feet under the dock floor, is 18 feet 6 inches in width, and the back has three off-sets of 12 inches each.

Altogether, a length of about 1,585 lineal feet of this section was built, of which 530 feet were made with concrete pockets. The remainder of the length was built solid, with rubble masonry faced with ashlar, the pockets being dispensed with, as they entailed more skilled labour, and effected but little saving. Although slight settlements have occurred, and were to be expected from the nature of the foundations, and from the backing being so exceptionally heavy and difficult to deal with, none of them have affected this part of the wall in any serious degree.

The remainder of the dock walls was built in a trench. A curved profile (Fig. 8) was adopted, but the sectional area was slightly reduced, on account of the filling in behind being so much less. This consists of Portland cement concrete, mixed with rough blocks of stone up to the top of the trench, or about 17 feet above the footings, and from thence up to the level of the coping of rubble masonry, in both cases faced with ashlar work averaging about 2 feet thick. By thus building the lower part of the wall in concrete, and the upper in rubble, time was saved, as well as cost. The concrete sets more quickly than the rubble, and with ground so easily affected by wet weather, and so liable to settlement, this is a matter of great importance. The sand under the footings was generally at a higher level on the east than on the west side. It

was, however, much more irregular, and full of abrupt changes in level. For a distance of about 440 feet from the north end, it occurred at an average level of 7 feet under the dock floor, almost free of water, and so hard that a bar of iron could with difficulty be forced into it. At this point, however, it dipped 11 feet with an almost vertical face, and became wet and full of springs. In many places running sand poured in at the foot of the piles and through the joints of the poling boards, caused the bottom of the trench to assume a concave form and produced a subsidence of the ground on each side. In one instance a settlement of 5 inches of the whole ground on one side occurred, without, however, damaging the timbers of the trench.

Along the whole length of the east side, the wall had a tendency to slide, but the alignment remained good until it was almost fully backed up. The filling in behind the walls was done with the excavations from the dock. The stuff immediately in front of the wall was lifted up in skips and barrows, and tipped behind; it was punned in thin layers, and the slope of the ground was stepped for receiving it. Numerous weep holes were left in the wall, and vertical shoots surrounded with dry rubble were placed against the back and brought up to the top. During wet weather, however, the water drained imperfectly to the weep holes, and most of it was retained in the clay backing, which was gradually but thoroughly saturated.

When the east wall was finished and backed up to nearly its full height, and within a few days of the date fixed for letting water into the dock, a subsidence of about 140 yards of the most recently completed portion took place (Plate 1, Fig. 11). The movement was of a similar kind to that which occurred on the opposite side. At the apex or breach the wall had slipped forward 15 feet 6 inches, and sunk 7 feet 6 inches. The dock floor in front was thrown up 10 feet in height for a distance of about 60 feet. The breach in the wall was much larger than in the other case, and extended through the foundations. There were seven cracks at other places, about 6 inches wide at the top but gradually lessening towards the bottom, and none of them reaching the footings. This portion of the wall was founded at an average depth of 9 feet below the bottom of the dock, and the whole of the foundation moved forward with the slip. With the exception of the cracks above mentioned the masonry was not affected, and the face-work remained as perfect as when built. The line of the wall on each side of the breach, after the settlement had taken place, assumed an almost regular curve of 2,000 feet radius.

Another feature of the slip was the sudden and unexpected manner of its occurrence. The northern end of the east wall had moved out of place no less than 14 inches, and although the backing had been lightened and the movement stopped, some anxiety was felt regarding it; the portion that failed, however, showed a scarcely perceptible deflection from the original position, and no fear was entertained for its safety. Both accidents happened on Sunday night, when there were no men on the work, but the Author had looked along the wall two hours before the occurrence of the latter failure, and observed nothing unusual in its condition.

In considering the means to be adopted for making good the slip, the chief thing kept in view was the necessity of admitting water to the dock with as little delay as possible, in order to avoid further risk to the walls.

To rebuild the wall on fresh foundations would have occupied at least six months, and that during the winter season. Under these circumstances, and as the curvature which it had assumed was not unsuitable for forming a quay wall, it was determined to build on the top of the existing masonry. Opposite the breach a trench was dug, about 40 feet in length, 4 feet in width, and to a depth of 4 feet below the dock floor. This was filled with Portland cement concrete. A face-work of brick in cement, 3 feet in thickness, was then carried up about 15 feet above the dock floor, and all cracks having been also filled up with cement grout, water was admitted to the dock up to this level. Behind the wall at this place, a large counterfort was built of the form shown in Fig. 11. It was founded upon sixty-three piles, driven 4 feet 6 inches from centre to centre each way, and connected by capsills secured to a long cross balk built into the new masonry. These timbers were roughly planked, and the counterfort brought up to nearly the full height of the wall, in lime concrete surrounded by thin walls of rubble. Five other counterforts, of a smaller size, built on piles in the same manner, were placed at various distances along the back of that part of the wall which had slipped. The whole of the masonry was carried up, together with these counterforts, to the level of the coping; the wall was backed up, and the water fully admitted to the dock. Since this was done, no further movement has been observed in any portion of the dock walls.

Two large brick sheds or warehouses adjoining the portions of the wall that gave way were partially destroyed by the slip. In

one of them the wall on the dock side, 40 feet from the coping, was built on a foundation of rubble, with counterforts, and this foundation, although drawn out of perpendicular by the slip, was used in rebuilding the warehouse; but in the other case, where no counterforts had been used, the foundation was completely overturned, and had to be pulled out and one of piles substituted.

### Excavations.

The earthwork chiefly consisted of clay, which, though easy to shift in good weather, was slow and expensive to manipulate in wet. Unfortunately, during the progress of the work the rainfall was very heavy, and not only greatly increased the cost of excavation and delayed progress, but so deteriorated the backing as to subject the stability of the walls to an unduly severe test.

Altogether, upwards of 1,750,000 cubic yards of material were shifted from the dock basin, lock, entrance channel, and foundations. Of this quantity, about 150,000 cubic yards were dredged from the entrance and discharged from hopper barges at a shallow part of the Bristol Channel, about 3 miles from the works. The entrance was dredged to the level of low water of equinoctial spring tides. The flow and ebb of the tide up to the lock, assisted by a little scouring, has been sufficient to keep this channel to its depth, the tendency being rather to deepen than to shoal.

From 10,000 to 40,000 cubic yards of material were excavated per month, and removed in a variety of ways, including locomotive roads, wagon roads worked with horses, inclines and stationary engines, swing and horse roads, and trolly roads with skips and portable steam cranes.

### Prices of the Work, &c.

It has been pointed out that the excavations were unusually costly in wet weather. The price, then, in fact, was more than double what it was in dry weather. Not only was it impossible to tip the stuff out of the wagons, which had therefore to be cast out, but the breakage of plant and the maintenance of temporary roads were greatly increased, while much less work was executed, without lessening the outlay. Part of the excavations being tidal work also added to the cost. Altogether, the average price, including a portion of the pumping expenses, was about 1*s.* 6*d.* per cubic yard.

The price of masonry has also been high, all the materials having

to be brought from distant places. A large portion of stone came from Tintern, where quarries were opened specially for the work. Some excellent Old Red Sandstone, intermixed with beds of conglomerate, was there found in large blocks, the best of which were selected for the face-work, while the rest was used for backing. This stone is exceedingly hard, and costly both to quarry and to dress, but it is very durable, and has a pleasing appearance. It cost, alongside the jetties at the dock, 5*s.* 6*d.* per ton, and could not be dressed for face-work under 10*s.* per square yard. A large quantity of much cheaper stone, for facing the walls, was obtained from Radyr quarries, near Cardiff. This was a red conglomerate, and came in large blocks, dressed and ready for setting. It averaged in thickness 2 feet, and it cost about 20*s.* per square yard when fixed in place. Besides these, blue limestone was obtained from Clifton. This was easy to quarry, and cost, for dressing, from 2*s.* to 3*s.* less per square yard than the Tintern sandstone. The average price for rubble masonry was about 20*s.* per cubic yard, exclusive of the dressed face-work, which was about 2 feet thick, and which cost about 2*s.* per cubic foot. Most of the finer ashlar for the lock was brought from the Forest of Dean, and was delivered in scabbled blocks alongside the jetties for 1*s.* 9*d.* per cubic foot. The cost of dressing, however, including waste and setting in place, brought the price up to 3*s.* 6*d.* per cubic foot. The granite for sills and copings came from Cornwall, and was delivered, dressed and ready to be set, at 3*s.* per cubic foot. The cost of the hollow quoins, also of Cornish granite, was 4*s.* 6*d.* per cubic foot, and 10*s.* per superficial foot for dressing with axes for fitting the heel post.

The Portland cement concrete of the east wall consisted of materials mixed in the following proportions: 1 of Portland cement, 3 of sand and gravel, and 5 of stone broken to a small size in one of Blake's crushers. These materials were partly mixed by hand and partly by a Messent concrete mixer. When mixed by hand, the materials were spread out on a wooden platform, and turned over with shovels, three times dry and three times wet. The concrete made in the mixer was revolved six times and a half, and the quantity turned out per diem was about 40 cubic yards. The machine work was the slower process, but produced better concrete. Large blocks of stone were mixed with the concrete, care being taken to keep them at certain distances apart. By these means a saving of cost was effected, the proportion being thus increased to 10 to 1. The average price of this concrete was

about 16*s.* per cubic yard, being 4*s.* less per cubic yard than rubble masonry.

The lime concrete used for the foundations, &c., was mixed in the proportions of 6 to 1, viz., 1 of lime, 2 of sand, 2 of ashes, and 2 of broken stone. It cost about 10*s.* per cubic yard. The lime for the mortar and concrete was obtained from Aberthaw pebbles burnt in kilns upon the works. It was mixed for making mortar in the proportion of 1 of lime to 2½ of mixed sand and ashes, and was ground in a mortar mill, twenty minutes being allowed for rough and forty minutes for fine mortar. Experience shows that 1 ton of Aberthaw limestone will produce, when burned, 0·64 ton of lime, being a loss through burning of 36 per cent.; that 1 ton of burnt lime gives 1·28 ton of slaked lime; and that the cost of burnt lime is 11*s.* 6*d.* per ton, including a charge for the cost of the kiln.

The proportion of mortar to stone in the rubble masonry was between one-third and one-fourth.

A careful account was kept of the cost of the dock gates. The first cost of timber for heel and mitre posts was 4*s.* per cubic foot; of the ribs, posts, and walings, 2*s.* per cubic foot. These prices, when reduced to an average, give:

| | Per cubic foot. | |
|---|---|---|
| | *s.* | *d.* |
| Timber in the gates | 2 | 5½ |
| Preparing and fitting | 2 | 6½ |
| Erecting in place | 1 | 1½ |
| Straps and bolts | 1 | 11½ |
| Castings, including anchors, gate sluices, two sets of rollers and paths to each leaf, pivots and chain-roller boxes, but excluding all mason's work | 2 | 5 |
| Pumping, staff, and contingencies | 1 | 0½ |
| Total cost per cubic foot on net quantity of timber in gates = | 11 | 6 |

| | £ | *s.* | *d.* |
|---|---|---|---|
| This price resolved into cost per square foot of superficial area of back of gate | 1 | 6 | 1⅔ |
| Or, taking the exact width between the copings and the height, viz., 70×48, gives per square foot | 1 | 13 | 2¾ |

| | | | |
|---|---|---|---|
| The net quantity of timber in one pair of outer gates is 9,710 cubic feet. The total cost of the timber work is | 2,957 | 8 | 0 |
| Ironwork | 2,121 | 0 | 0 |
| Pumping, staff, and contingencies | 507 | 16 | 9 |
| Total cost for one pair of gates | £5,586 | 4 | 9 |

The following is an abstract of the cost of the various works:

| | £. |
|---|---|
| Excavations | 112,250 |
| River walls | 7,896 |
| Lock | 85,000 |
| Lock gates | 18,755 |
| Dock walls | 75,728 |
| Apron of lock | 2,000 |
| Temporary wooden dam | 1,500 |
| Bollards | 1,620 |
| Metalling quays | 1,000 |
| Fencing | 1,500 |
| Hydraulic machinery | 18,000 |
| Hydraulic engine-house | 2,500 |
| Custom-house | 250 |
| Mooring buoys and dummies | 700 |
| Permanent way | 3,000 |
| Warehouse sheds | 12,000 |
| Dock-master's house | 1,000 |
| Miscellaneous | 2,000 |
| | £346,699 |

The Chief Engineers of the undertaking were Messrs. Brunlees and M'Kerrow, MM. Inst. C.E.; the Contractor was Mr. W. F. Lawrence, Assoc. Inst. C.E.; the Resident Engineer being the Author.

The communication is accompanied by numerous drawings and diagrams, from which Plates 1 and 2, and one wood-cut have been compiled.

No. 1,553.—"The River Lagan and Harbour of Belfast." By Thomas Ross Salmond, M. Inst. C.E.[1]

The town of Belfast, or as it was originally termed *Beala-farsad*, is situated at the embouchure of the river Lagan. The river rises on the northern escarpments of the Slieve Croob mountain range, in the County of Down, westward of Ballynahinch, and, during a devious course of about 35 miles, drains an area of 227 square miles. It passes Dromara, Dromore, Moira, and Lisburn, and finally discharges itself into the southernmost extremity of a bay, known at various times by different appellations, such as Lough Largh, Lough Bangor, Bay of Knockfergus, and Belfast Lough.

About two and a half centuries back, the harbour of Belfast was but an insignificant creek of the river Lagan; being in point of fact inferior to that of Carrickfergus, the only stronghold in the bay at that period.

Belfast harbour, anterior to the year 1637, was under no regular form of government, and was at that time the private property of the Chichester family. The Corporation of Carrickfergus by Royal Charter claimed, amongst other trading monopolies, one-third of all the custom duties payable on goods imported into Belfast; but in the year 1637 an impetus to trade, aided by the natural facilities of the place, led to the development of Belfast harbour into a port of considerable importance. In that year the immunities of the Corporation were purchased by Earl Strafford; a custom-house was subsequently established, and the revenue business transferred to Belfast from Carrickfergus.

The first attempt to bring Belfast harbour under the conservancy of a public corporation was made in the year 1729, by an Act, 3 George II., which constituted the sovereign and free burgesses of the town conservators of the harbour and port. The reason assigned in the Act for this interference of the legislature was, that, "The harbour had become extremely shallow, by which means voyages have been prolonged, to the very great prejudice of trade, and his Majesty put to extraordinary expense and charge, in keeping officers longer on board the vessels trading to and from the said town, than would be needful had the said

[1] The discussion upon this Paper was taken in connection with that upon the preceding Paper and the one following, and occupied portions of two evenings.

harbour and channel been preserved in the same condition as it formerly was." Fifty-six years subsequent to the passing of the above Act, another Act, 25 Geo. III. cap. 64, was passed, repealing the former Act, and providing for the constitution of a special corporate body, with increased powers, who should undertake the entire government of the concerns of the port. The advent of the new Harbour Commissioners marked the commencement of the most important engineering improvements of the port and harbour of Belfast.

At that time the town was situated on a bend of the river Lagan; the tide flowed up this river a short distance above the town, but ebbed almost entirely out, leaving a narrow serpentine channel of fresh water, which flowed through extensive flat sands. This curved channel was extremely shallow just opposite to the town, there being only from 2 feet to 4½ feet of water at low tide; increasing in depth gradually until it reached "the Flats," a distance of almost 2½ miles, where, at its point of confluence with the Seal channel, it had a depth of about 8 feet at low water of spring tides. The depth gradually increased from this point, for a distance of about ½ mile, to 16 feet at low water. Here the Garmoyle roads commenced, and at low water of spring tides a depth of from 18 to 20 feet was attainable, where vessels were obliged to wait until the tide suited their being brought up to the town, an operation attended with some risk, especially with vessels of considerable draught and tonnage. Vessels drawing more than 10 feet of water could not approach the town during neap tides; and during spring tides vessels of not more than 14 feet draught could with safety be brought up; all vessels therefore of heavier draught were obliged to lighten their cargoes into barges or scows at Garmoyle, before they could proceed to the town.

The docks and quays for the accommodation of the shipping were May's dock, Hanover quay, Merchant's dock, Limekiln dock, Donegal quay, and Ritchie's dock. They were only tidal docks, or recesses, capable of receiving small boats or sloops. The quayage amounted to about 1,780 lineal feet, the half of which could only be counted upon as suitable for vessels of large burthen, owing to the depth at which the quay walls were originally founded.

The first attempt towards improving the channel by the new Harbour Commissioners was the removal of several artificial fords which formed bars across the river Lagan; and the deepening by dredging of the bed of the river. The facilities for navigation were in 1786 improved by the old south channel course being

marked with perches and buoys, from the town quays down to the Garmoyle roads. The improvement of the approaches to the town from Garmoyle appeared to be at that time the great desideratum at which the Commissioners aimed. To this they were evidently driven by the serious delays and consequent loss, together with the expense necessarily incurred in lightening ships at Garmoyle.

Reports were received from many engineers of eminence, recommending various schemes for improving the channel—as from Mr. John Rennie, sen., in 1821; Mr. John Rennie, jun., in 1826; Mr. Telford, in 1829; Mr. John Rennie, jun., in 1829; and Mr. Rhodes, in 1834. These engineers, although they differed as to site, all reported in favour of the formation of a ship canal, or canals, with locks and gates, leading to proposed floating docks, in order to obviate the troublesome and tortuous course of the existing approaches from deep water at Garmoyle. Messrs. Walker and Burges in 1830, however, gave it as their opinion that a tidal channel, cut in a straight line through the Flats and "Ballast bank reach," from the buoy of the Flats at the Seal channel to the entrance to what was at that time called Dunbar's dock, would be less expensive, and more suited to the requirements of the Belfast trade. They further suggested the deepening of the existing harbour, and the construction of new quays, so as to secure at least 12 feet depth of water at low tide, with a width of channel opposite the town of at least 350 feet. This plan was selected by the Corporation, and in the year 1831 it received the royal assent. Opposition was, however, raised to the carrying out of the scheme, by a section of the merchants of the town, which proved a barrier to the procuring of the requisite funds to carry out the work; and eventually a new Act was obtained in the year 1837, 1 Vict. cap. 76. The works ordered to be carried out in connection therewith were:

1st. The construction of a new navigable channel for the river Lagan, through the slob-ground, from the Dunbar's dock entrance to a point in the old channel course, nearly opposite Thompson's Tower; thereby cutting away the first bend of the old channel next the town.

2nd. The purchase of all the existing docks and quays owned by private individuals, and the widening and improving of the same.

3rd. The formation of a second straight cutting or channel through "the Flats," in continuation of the first cut to the buoy of the Flats, where deep water would be secured. This channel would cut away the second bend of the old channel, and the result

would be a straight course for the river Lagan, from the town quays to the mouth of the Seal channel near Garmoyle. Other works of minor importance were also contemplated.

Reviewing the extensive improvements which have been carried out at the port of Belfast from the time of Messrs. Walker and Burges' report, it is obvious that the Harbour Commissioners of that period were fortunate in their choice of a design, and in the arrangements of their future dock and harbour works, as, had they adopted any of the canal schemes, they would have considerably trammelled the operations of their successors for the extension and improvement of the river and harbour works.

There can be little doubt that tidal approaches to docks and quays possess advantages over a canal system with locks, gates, &c., especially in a harbour such as Belfast, where the range of tide is small; and that tidal approaches, so far as this port is concerned, are superior to a canal system is evident. In the first instance, by the construction of a canal, the harbour and dock works would have been cut off from communication, except by branch canals, with the river Lagan. The harbour would thereby have been deprived of the benefit of a large quantity of back water, the advantages of which, for scouring purposes can scarcely be overrated. Secondly, the unavoidable delay, to vessels entering and leaving, would have been a matter of serious importance; as well as the expense of construction and maintenance, the increased amount of dredging requisite to preserve the proper depth of water, and the cutting of a new course for the river Lagan, in order to keep open the navigation.

The first portion of the scheme executed consisted in the formation of the section of the new channel, from Dunbar's dock to Thompson's tower. This work was completed, and opened for traffic, in the year 1841; the cutting was about 3,000 feet long, 370 feet broad, and 12 feet deep at low water. The excavated soil was used in the formation of the side embankments, and in making up a parcel of valuable property called the Queen's Island, containing about 17 acres, a large portion of which has been found suitable for ship-building purposes; some of the largest merchant vessels afloat having been built at that place.

Between the years 1846 and 1849, the second cut of the new channel, named the Victoria Channel, was executed. This cutting through "the Flats" lies between the Twin Islands, formed by the excavated material from the bed of the cut, cast up so as to produce slopes of about 4 to 1, the channel faces of which were

pitched with heavy stones. The cutting was about 3,300 feet long, the width at the top being about 450 feet, and the depth about 23 feet at high water.

It had been anticipated, by the engineers who reported on these works, that the formation of the straight channel would lessen the amount of dredging to be done in the lower portion of the river; and the fact of the upper section of the river having maintained its depth without dredging confirmed that opinion. The increased depth, however, which had to be provided in the river, in front of the quays, being much below its natural bed, will always necessitate additional dredging to prevent the bed silting up. This would of course increase, as the sewage of the town increases, if it be discharged into the river Lagan.

A commencement was made in the year 1858 towards the regular deepening of the navigable channel, from the upper end of the harbour at Donegal quay; and so great was the improvement effected by the dredging of the channel, between the years 1858 and 1861, that vessels of 22½ feet draught were enabled to reach the quays at spring tides without lightening their burthen. Dredging operations have been steadily carried on from that date, with the view of deepening the harbour to as great an extent as the structure of the old quays will admit of; and the depth of water is now sufficient to admit, at all times of the tide, of a large fleet of cross-channel steamers which regularly trade to this port from various parts of Great Britain and Ireland.

The existing navigable channel at Belfast is quite straight for a distance of 2 miles northward from the Clarendon dock entrance, and it has an average depth below low water of about 12 feet. From the north end of the Twin Islands the channel is serpentine for about 1 mile towards the pool of Garmoyle, which has a depth of 20 feet at low water. From this place it follows for another mile a straight course through Whitehouse roads, the depth varying between 13 and 16 feet at low tide, and curves again towards the north-east, across a bar about 4,000 feet in length with 11 feet depth of water over it, opposite the Oyster bank, into the open lough. Here the least depth of water is 2 fathoms at low tide, and the depth gradually increases seawards.

The improvement of the harbour approaches has for many years engaged the attention of the Belfast Harbour Trust, who appear disposed to render the channel between the harbour and lough as easy of access as possible, and to provide a sufficient depth of water to admit of vessels drawing 24 feet coming up to the quays at

high water of ordinary neap tides. Having that object in view, the attention of Messrs. Bell and Miller, MM. Inst. C.E., was directed to the subject. When called upon to report upon the general improvement of the Port of Belfast in the year 1862, these engineers suggested that, to improve the present channel so as to render it available at all times for the navigation of large vessels, it should be deepened to the extent of not less than 15 feet at low water; and to obviate the present circuitous route through Whitehouse roads they further suggested that a straight cut, or channel, should be formed across the Holywood bank, or slob grounds, and between that bank and the Oyster bank; the lines of this proposed channel to be in one with those of the Victoria channel. This they advocated, having regard to the desirability of ultimately connecting the proposed channel across the Holywood bank with the Victoria channel by a straight cutting, and thereby securing a direct navigable course from the north end of Donegal quay to the deep water. Sir John Hawkshaw, also, in his report to the Belfast Harbour Trust in the year 1870, referred incidentally to the direct channel to deep water, and laid down lines which nearly coincided with those proposed by Messrs. Bell and Miller.

The advisability of a straight course for the purposes of navigation is generally admitted, affording, as it undoubtedly will, many advantages over the existing mode of navigation. The pilotage establishment, for instance, which may be considered necessary, chiefly owing to the existence of the crooked and tortuous route from the Twin Islands to deep water, might be remodelled in such manner as to reduce, if not entirely abolish, the pilotage dues. A saving might also be effected in the lighting of the harbour approaches, as at least two of the lighthouses would be rendered obsolete by the carrying out of this scheme. The saving of time, together with the reduction of risk of vessels taking the ground, as occasionally happens on the banks of the present serpentine channel, are desirable.

The extensive dock and quay works recently carried out, together with those in course of construction, being designed with a view to obtaining a depth of water along the quays of at least 15 feet at low tides, the requirements of the larger class of timber and grain vessels which now frequent this port, demand a considerable increase in the depth of water in the channel between Belfast and the Holywood lighthouse. Moreover, the question of the formation of a channel of suitable depth from that point seaward, whether it be across the Holywood bank or across the bar at the

entrance to Whitehouse Roads, is a subject which requires, not only immediate attention, but mature deliberation, as it is highly probable that whatever site may now be determined upon will become the ultimate course between Garmoyle and the sea.

The schemes at present in competition, so far as regards this portion of the proposed channel improvements, are two.

1st. That proposed by Messrs. Bell and Miller, in 1862, which consists of the formation of a straight channel from Garmoyle to deep water, the centre line of which course would coincide with that of the channel between the Twin Islands. In their report they refer to the crowding of vessels outward bound, which are frequently detained at Whitehouse roads owing to adverse winds; they also refer to the circuitous route which vessels have to take around the buoy of the Oyster bank in order to follow the course of the deepest water; these they consider to be drawbacks, "which it would be very desirable to 'remove' as far as possible," and to obviate which they proposed the straight channel course. They further gave it as their opinion that "a straight deep-water channel, all the way to the harbour, which could be entered at all times without the aid of pilots, was a desideratum which should always be looked forward to."

2nd. The alternative scheme is the formation of a channel from Whitehouse roads to deep water, across the bar opposite the Oyster bank. This proposed channel would follow the line of the present route at low tide, from Whitehouse roads to the sea.

Both the foregoing schemes appear open to objection. No. 1, mainly on the ground of cost of execution, from the fact of the present surface of the sea bed on its site being at a considerably higher level than that of No. 2; and the length of the former cutting being greater than that of the latter. The excavation, in the case of scheme No. 1, would amount to almost treble the quantity necessary for No. 2. Again, it has been urged as an objection to No. 1 scheme, that the effect of a straight channel, from deep water direct to the quays, would be injurious to the shipping berthed thereat, as the "send" of the sea, during the prevalence of north and east winds, would be likely to affect the tranquillity of the upper harbour, which is at present preserved to a great extent, by the existence of the east and west slob-banks, which constitute a natural barrier against the sea. Although it is undoubtedly advisable that at some future period a straight channel should be made from the Twin Islands to Garmoyle, the mouth of such channel would be to some extent protected by that portion of the

east or Holywood bank, through which it was proposed that No. 1 channel should be carried.

Having thus far dealt chiefly with the approaches to the harbour and docks of Belfast, a description will be given of the shipping accommodation at present available at the port (Plate 3, Fig. 1). The principal lines of quayage extend along both sides of the navigable channel of the river Lagan; opening out from which on either side are inland docks and tidal basins; the Clarendon, Prince's, and Spencer docks (Plate 3. Fig. 2), as also the Abercorn basin, and Entrance basin, convenient to Spencer dock, are tidal, the Dufferin dock being the only floating dock at this port. The graving dock accommodation is limited to three docks, the Hamilton, of recent construction, and two Clarendon graving docks, which were constructed upwards of half a century ago.

Table 1 illustrates the sizes and description of the various docks and quays at the port of Belfast.

TABLE 1.

| Year opened. | Name. | Depth below Low Water Level. | Widths of River and Entrance. | Area of Water. | Quayage. |
|---|---|---|---|---|---|
| | | Feet. | Feet. | Acres. Roods. Poles. | Lineal ft. |
| 1849 | Donegal Quay . . | .. | River 390 to 570 | .. | 2,325 |
| 1848 | Canal Quay . . . | .. | .. | .. | 200 |
| 1851 | Clarendon Dock. . | .. | 50 entrance. | 3 3 10 | 1,992 |
| 1800 | Graving Dock, No. 1 | .. | 30 „ | Length on floor 245 feet. Breadth at top 50 feet. | .. |
| 1826 | „ „ No. 2 | .. | 36 „ | Length on floor 287 feet. Breadth on top 58 feet. | .. |
| 1849 | Prince's Quay . . | .. | .. | .. | 825 |
| 1832 | Prince's Dock . . | .. | 60 „ | 3 3 18 | 1,716 |
| 1874 | Albert Quay . . | .. | River 360. | .. | 2,040 |
| 1872 | Dufferin Dock . . | 15 | 60 entrance. | 3 1 12 | 1,645 |
| 1872 | Spencer Dock . . | 15 | 80 „ | 7 1 39 | 1,900 |
| 1872 | Entrance Basin . . | 15 | .. | 5 0 2 | 200 |
| 1877 | Queen's Quay . . | .. | River 390 to 570 | .. | 2,150 |
| 1867 | Abercorn Basin . . | 12 | Open basin. 700 by 700 | 12 1 39 | 1,370 |
| 1867 | Hamilton Graving Dock . . . . | On sill. 5·60 | 60 entrance. | .. | .. |

The dimensions of the graving docks at this port are as follow:

TABLE 2.—GRAVING DOCKS

| | *Dock No. 1.* | *Dock No. 2.* | *Hamilton Graving Dock.* |
|---|---|---|---|
| | Feet. Ins. | Feet. Ins. | Feet. Ins. |
| Length on floor | 245 0 | 287 0 | 451 6 |
| „ at top | 252 6 | 299 0 | 470 0 |
| Breadth at top | 50 0 | 58 0 | 84 6 |
| „ at bottom | 35 6 | 34 0 | 50 0 |
| Level of sill, which is 3 feet above Ordnance datum | above 1 9 | Datum | below 5 7 |
| Depth of dock from coping to floor | 14 0 | 15 6 | 22 9 |
| Width of entrance | 30 0 | 36 0 | 60 0 |

Rather more than one-half of the quayage at this port is constructed of stone work, and the remainder of timber. On the county Down side of the harbour the foundation subsoil is good, being chiefly sand and stiff red clay; but on the county Antrim side it is principally soft blue clay, alluvial deposit, locally termed "sleetch." This, in many cases, exists for a depth of upwards of 66 feet below the surface, before a firm stratum of sand or clay is reached. In dealing with foundations of this class the engineers, from time to time, resorted to various expedients. Between the years 1844 and 1847, when the construction of new quays was undertaken on both sides of the river northwards of the Queen's bridge, from the designs of Messrs. Walker and Burges, a timber wharf facing was adopted, which was tied back by iron rods and stay piles. This wharf (Plate 3, Fig. 3) consists of a front row of supporting piles, 36 feet in length by 13½ inches square, the piles being spaced 5 feet apart from centre to centre longitudinally. In front of these piles a close row of sheet piles was driven, 20 feet long by 8 inches in thickness, the piles having a batter of 1 in 12, an iron wale 6 inches deep by 1 inch thick being secured along the entire front. Behind these sheet piles the front face of the main piles is cleaded, with 5-inch close planking, spiked to the piles. On each second main pile a vertical fender, 13½ inches square, is secured by four cast-iron angle brackets to the front planking. The coping is of timber, 12 inches by 6 inches. This facing is tied back by five 2-inch round iron tie-rods to each main pile. The rods are secured to three stay piles, one 24 feet, and two 20 feet in length each, spaced 5 feet apart from centre to centre longitudinally. A line of 4-inch planking, 4 feet 6 inches in depth, is spiked to the front face of the back stay piles for the entire length of the wharf. The backing up of these wharfs was composed, for the most part, of dredgings from the river, which

was deepened in front of the new quays. It consisted of sand and sleetch. The depth to be filled behind the wharf was about 19 feet below the level of the quay, or 5 feet below low water, that being the level of the bed of the river into which the piles were driven. Very few of the piles entered the hard sub-stratum. The wharf nevertheless suited the requirements of the port at the time when it was erected, being sufficiently stable, and admitting of dredging being carried on to a depth of about 8 feet below low water close to it. The cost of this class of work is comparatively small. At the time of erection it was only about £12 12*s.* per lineal foot of wharf, and includes "filling," to the extent of about 170 cubic yards to each lineal foot. The Queen's quay portion of this work, which was erected in 1844–46, lasted for about thirty years, having been recently removed, and reconstructed on a different principle. Considerable trouble and expense were involved during the latter ten years of the existence of these old quays, consequent upon the decay of the timber, principally the front planking, fenders, and coping; and upon the periodical breaking of the iron tie-rods, which were much reduced by corrosion.

In consequence of the influx of a larger class of shipping to the port of Belfast it was found necessary, in the year 1864, to extend the existing dock accommodation; and, in doing so, to provide for a greater depth of water than could be procured opposite the old timber quays. It was also considered desirable that the proposed new works should be executed in stone. The depth of water for which provision was made was, on the county Down side, Abercorn basin, 10 feet at average low water; and, on the county Antrim side, 15 feet at low tide.

The structure of the wall of Abercorn basin is shown in Plate 3, Fig. 4. The foundation-bed was ascertained to be firm sand, so that it was not considered necessary to do more than drive in front of the wall a close row of sheet piles, 12 feet long by 6 inches in thickness, in order to confine the sand. At the Dufferin and Spencer docks the sub-strata were of such a soft and unreliable character that an artificial foundation of bearing piles had to be resorted to. Figs. 5 and 6 represent the structure of this wall, the section of which varied according to circumstances, from that of Fig. 5 to that of Fig. 6. The foundation consisted of five rows of round larch piles, each 15 feet long, and averaging 10 inches at the top and 7 inches at the toe, driven at distances apart, longitudinally and transversely, of 4 feet 6 inches from centre to centre. Baltic sleepers, 12 inches broad by 6 inches thick, were laid along and across the

heads of the piles, to which they were bolted by 18-inch hardwood treenails. At the top of this timber a bed of concrete, 18 inches in depth, was spread over the entire surface, and upon it the superstructure of the masonry wall was raised. These walls have from the first exhibited symptoms of weakness, due, probably, not so much to any defect in the design, as to the lightness of the piling timber, and also to the base of the wall not having been sunk sufficiently deep below the bottom of the dock to withstand the lateral thrust consequent upon the backing materials behind the walls. The first signs of settlement were noticed shortly after the commencement of the backing up of the walls. As the backing was proceeded with, the symptoms became more serious. When, however, the water was let in, the counter hydraulic pressure contributed in some slight measure to support the structure. Several eminent engineers, at various times, reported upon the best means of securing these walls—Sir John Hawkshaw, Past-President Inst. C.E., the late Mr. John B. Hartley, M. Inst. C.E., and Mr. John F. Ure, M. Inst. C.E.; and various methods were adopted to arrest the settlement, prior to the tidal water being let into the dock works. When it was ascertained that the walls were settling in a lateral direction, following that of the line of pressure from behind, footings were resorted to, as recommended by Mr. Hartley (Plate 3, Fig. 7). These footings consisted of a row of sheet piles, 12 feet in length and 6 inches in thickness, driven in front of, and parallel to, the walls at a distance of 12 feet, and at a level of 2 feet below the sheet piles of the main walls. At the back of the sheeting, and spiked to it, were two wales, 12 inches broad by 6 inches thick; and on the front of the sheet piling of the wall a similar wale was fixed below the original one. Between the wales of the footing piles, and those of the wall, shores or struts, 12 inches square, were fixed, and the spaces between the two rows of piles were built up with rubble masonry for a depth of 3 feet 6 inches. The entire footing covered an area of 13 feet by 12 feet. These footings were built at such points as showed indications of settlement, and were of great service in arresting the outward movement of the wall. Besides these, however, tie-rods were also adopted, and were productive of good results. The rods were of lengths varying between 60 feet and 120 feet, and were tied back to stay piles, driven in sets of three, each pile being 28 feet in length and 13 inches square, driven to a batter of 1 in 12. The heads of the piles were, when driven, 10 feet below the coping, or about 6 inches above low-water level. On the face of the piles was fixed a sheeting of 4½-inch planking, 18 feet long

and 7 feet deep, spread over each set of three piles. A runner, 18 feet long and 13 inches square, was secured to the back of the stay piles; and through this runner, at a little above low-water level, the tie-rod, which is 2½ inches in diameter, is screwed. In the front of the wall, about low-water line, a hole 1 foot 9 inches square is sunk 10 inches into the face. In this recess a heavy cast-iron washer is set, and against it the tie-rod is tightly screwed; the cavity is then filled up with masonry, and the washer thereby concealed from view.

The manner in which the walls of these docks have settled leaves but little doubt as to the causes of failure, and points to the weakness of the piling, and the insufficient depth of the footings. However, another element should be taken into consideration, and that is, the material at the Engineer's disposal for filling in behind the walls, which was of the same soft consistency as the foundation subsoil. This is an undesirable material for the purpose; and the chances are great that, had it been practicable to procure a sufficient quantity of light material for filling in immediately behind the walls, such as ashes, brick rubbish, &c., and the remainder of the backing material of stiff clay, or sand, the walls might have retained their original conditions of form and stability. Such, however, was not the case, and the Engineer was constrained to adopt the most suitable of the materials at his disposal. When it is remembered that in most cases, in excavating for the foundations of this dock, the slopes had to be formed, for the sake of stability, at 5 and 6 to 1, and in no case less than 3 to 1; that in three or four instances extensive slips occurred; and considering that the only backing material available was a pulpy semi-fluid mass, occupying a large area and depth, and exercising an enormous lateral thrust from behind against the walls, it will scarcely be wondered that the walls yielded as they did, in one instance completely collapsing. The instance occurred on the north-west side of the entrance to the Spencer tidal dock two years after its erection, when a length of about 70 yards fell into the entrance. Here the piling was evidently too light, as the wall fell outwards at the top, and, revolving on its toe, broke the bearing piles across, a little above their middle, about 6 or 7 feet from the bottom of the wall, the sleepers, concrete, and parts of the piles, adhering to the lower portions of the masonry. The manner in which this wall collapsed is shown in Plate 3, Fig. 8. The fallen wall was raised by diving operations, and it is now being reconstructed as shown in Fig. 9. It is composed of concrete up to

2 feet 3 inches above low water, between two close rows of sheet piles, 44 feet long by 12 inches in thickness. Intermediate piles of the same length are also driven longitudinally and transversely at distances of 4 feet apart from centre to centre. On this substructure the masonry wall is erected, and is backed up with light filling. Tie-rods of wrought iron, 3 inches in diameter, are also used for the purpose of giving additional security to the wall. Fears having been entertained as to the safety of the south-east side of the entrance, it was considered prudent to relieve the backing up behind the walls, to take down part of the masonry (Plate 3, Fig. 10), and instead of rebuilding upon the same foundation, to erect a framed timber structure.

A section of the timber wharf recently erected on Queen's quay is shown in Fig. 11. The new line of this quay is set back, in some parts 120 feet behind the old wharf, with the object of affording an opportunity, when reconstructing the Donegal quay opposite, of setting that quay out into the water, to give a greater width than the present quay. This, at the point referred to, is much too narrow for the immediate requirements of the traffic, especially in view of the intended extension of the quay tramways. The Queen's quay is about 2,150 feet long. There are three rows of bearing piles of pitch pine timber, 12 inches square; the front row is 48 feet in length, the middle row 43 feet, and the back row 40 feet. The piles are driven 6 feet apart from centre to centre longitudinally. Between the piles of the front row, sheet piles of American elm timber, 11 inches in thickness, are driven close together, their length being 37 feet. The front and back rows of the main piles are fastened together by diagonal braces, 12 inches deep by 6 inches wide, two to each set of three piles. The platform is composed of strong joists, 12 inches wide by 6 inches thick, supporting a timber floor 6 inches in thickness, which is covered with a layer of bitumen and paved with stone square sets. The back of the wharf is planked with timber 4 inches in thickness, against which is filled a backing of engine ashes, cinders, brick rubbish, or other light material. The space underneath the wharf, between the front and back rows of piles, is formed into a slight slope, which is paved with pitching stones, to prevent the water abrading the filled-in material; and the face of the wharf is cleaded with open timber work, to prevent the water depositing bulky matter on the slope. Mooring pawl piles of greenheart timber, 14 inches square, capped with cast-iron hoods, are driven every 60 feet apart along the wharf; and a number of sets of strong piles, 30 feet long, are driven 50 feet back from the wharf, and are connected with it by

tie-rods of wrought iron 2½ inches in diameter, to prevent the wharf being driven forward by any undue weight placed upon the platform, or by the weight of the materials by which it is backed up. The piling of this work is so designed that a depth of 16 feet at low water may be secured by dredging without injuring the stability of the superstructure.

The Albert quay, one of the old timber quays before referred to, was reconstructed on almost the same principle as that adopted at the Queen's quay. The only essential difference between them is that in the former, the subsoil being soft and pulpy, an additional row of sheeting piles was driven between the centre row of the main piles, the main piles were spaced at 5 feet apart from centre to centre longitudinally, and instead of American elm being used for the sheet piles, pitch pine was adopted.

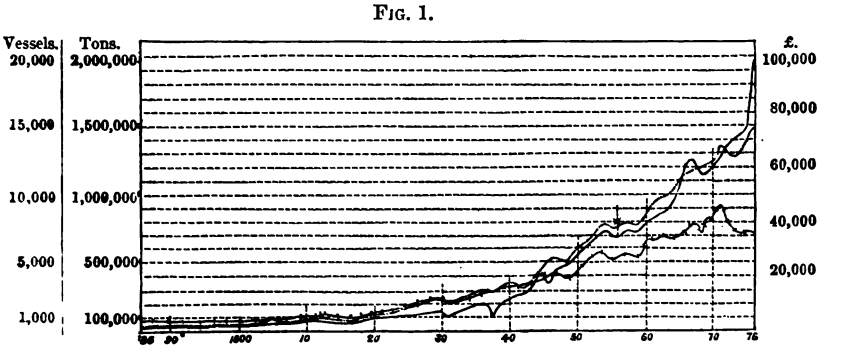
The rise of the tides at Belfast harbour above Ordnance datum is as follows:—

| | Feet. | Ins. |
|---|---|---|
| Average of low-water, springs . . . . . | 4 | 7 |
| „ „ neaps . . . . . | 5 | 4 |
| „ high-water, springs . . . . . | 13 | 5 |
| „ „ neaps . . . . . | 12 | 8 |

showing an average range of 8 feet 10 inches at spring tides, and of 7 feet 4 inches at neaps. The highest spring tide on record was 17 feet 2 inches above Ordnance datum.

The number of vessels trading to the port of Belfast annually from the year 1786 and the annual revenue and tonnage for the same period are shown in Fig. 1. The revenue in 1786 was £1,558;

FIG. 1.




that of 1876 was £99,533 6*s*. The tonnage in 1786 was 38,421 tons, and in 1876 reached 1,497,585 tons.

This communication is accompanied by a series of drawings, from which Plate 3 and one woodcut have been compiled.

No. 1,577.—"Whitehaven Harbour and Dock Works." By JOHN EVELYN WILLIAMS, M. Inst. C.E.[1]

WHITEHAVEN being situated on a bold and exposed coast, it is not surprising that numerous schemes have been brought forward from time to time to take advantage of the opportunity which nature has bestowed upon the port.

In 1768 Smeaton inspected the harbour (Plate 4, Fig. 1) and proposed its enlargement by the construction of a north pier and the extension of the New quay. But as he apprehended that it would be many years before much relief could be afforded to the trade of the port by so extensive a work, he suggested, as a more expeditious and less costly alternative, the lengthening of the old quay for a distance of 30 yards. In 1804 Captain Huddart, R.N., proposed the extension of the bulwark and the narrowing of the entrance in order to tranquillise the north harbour. In 1814 Mr. John Rennie presented a design, and reported upon the enlargement and improvement of the harbour. Mr. Rennie advocated the prolongation of the new quay for a distance of 330 yards, and the extension of the north wall for a length of 200 yards, the pier-heads to terminate at a distance of 60 yards apart, and in a depth of 26 feet at high-water ordinary spring tides. A jetty, or spur, 100 feet long was to be constructed a short distance within each pier-head, so as to check the run of the sea into the harbour, and thus enable vessels to lay alongside the piers. The estimated cost of these works was £119,176. In 1821 Mr. William Chapman designed a pier 300 yards long, running seaward in two cants of about equal lengths, and in direction nearly north-west and south-west respectively, from the projecting elbow of the north jetty, the pier-head terminating 60 yards from the end of the new quay. The estimated cost of this work was £52,000.

It was not, however, until 1823, when Messrs. John Whidbey and John Rennie proposed the construction of the west pier (Plate 4, Fig. 1), that any practical steps were taken to further enlarge and improve the harbour of Whitehaven. In their report of May 1823, they stated: "The principal object we have in view is to obtain as much water as possible at low-water at the proposed pier-head, and

[1] The discussion upon this Paper was taken in connection with that upon the two preceding Papers, and occupied portions of two evenings.

also to make the water smooth within it, so that ships may enter with ease and safety within the pier at an early part of the tide." They suggested that the pier should extend for a distance of 335 yards from the new quay, the estimated cost of which was £67,274. The work was commenced in 1824, and two years later, when the construction of the pier had advanced a length of 116 yards, to where there was a depth of 6 feet at low-water spring tides, Mr. Rennie wrote as follows:—"The additional depth of water acquired by this will no doubt form a most important improvement; but the additional advantage of extending the first arm about 30 yards farther out in its present direction, and giving the second arm a proportional inclination farther seaward, will be so great that I cannot hesitate in recommending it. By this means an additional depth of 4 feet would be obtained, and there would then be always 10 feet of water within the pier at the lowest ebbs." It became evident, however, as the construction of the pier advanced seaward, that the harbour was rapidly silting up. This was no doubt owing to the structure intercepting the shore currents, carrying with them sand and other matter in suspension. Mr. Rennie proposed, in order to prevent the further deposition of sand within the harbour, that the circulation of the currents should be restored, by making an opening at the junction of the new and old work. Or, "since the important object of tranquillising the interior of the harbour had been largely effected, further progress seaward with the west pier should be deferred, and the north pier be at once proceeded with, and continued according to the original plan."

In 1831, when the west pier (Plate 4, Fig. 1) was completed to the commencement of the pier-head, a memorial, signed by a large number of shipmasters, was presented to the Harbour Trustees, which set forth—"That notwithstanding the acknowledged benefit arising from the erection of the new west pier in protecting the inner harbour, the difficulty in approaching it has been greatly increased with the wind from the S.S.E. to S.W.," and added, "that any farther extension of the pier would be attended with danger and difficulty to vessels entering or sailing from the port."

In 1833, Sir John Rennie (Mr. Rennie having in the meantime received the honour of knighthood) was requested by the Trustees to examine the harbour, in order to point out the most effective remedy for preventing the accumulation of sand. Sir John found an accumulation in some places 2 feet deep; and in his report stated:—"This accumulation varies more or less according to the prevalence of particular winds or tides, and is occasioned by the

counter or eddy current setting to the southward; this being charged with sand and other impurities, and being checked in its course by the harbour works, forms a deposition within them; and as it is increasing upon the whole, it is clear that, unless some counteracting cause be adopted, as originally intended, this deposition will continue to increase until its consequences become more serious." Sir John again urged upon the Trustees the importance of at once proceeding with the construction of the north pier which he stated could be carried out for a sum not exceeding £33,050, and by which "the eddy current from the northward would be diverted, and the sand which is now deposited within the harbour would be chiefly deposited elsewhere."

The construction of the north pier was commenced in 1833. On the 23rd of January, 1836, during a severe westerly gale, a large fleet of vessels that had previously sailed put back to port. One of them, the brig 'Musgrave,' in entering the harbour fouled one of the cranes engaged in completing the jetty or spur within the north pier-head, and became a total wreck. In consequence of this mishap, and of other accidents amongst the shipping in the harbour, a public meeting was held, and a copy of the resolution agreed to was sent to Sir John Rennie, who, in reply, reminded the Trustees that the head of the west pier had not yet been constructed as he had recommended. The seas, therefore, instead of being diverted by the round projecting head, were swept across the entrance, carrying the vessels too far to leeward to enter the harbour with safety.

In the following April the Trustees requested Captain Denham, R.N., Marine Surveyor of the port of Liverpool, to inspect and report upon the harbour. Captain Denham proposed the closing of the existing entrance, and the formation of a new one more inland through the north pier, facing Redness Point. This suggestion was not adopted. About the same time Messrs. James Walker and Jesse Hartley, at the request of Lord Lowther, on behalf of the Trustees, inspected the harbour, and reported their opinion as to the best mode of completing the entrance. They proposed that the west pier should be completed without further extension, by removing a portion of the last cant, and reconstructing it with a bold head curving seaward, so as to divert the waves and diminish the roll across the entrance. They also advocated the widening of the entrance by the removal of a length of about 90 yards of the outer portion of the north pier. The plans and reports of Captain Denham and of Messrs. Walker and Hartley, after having been referred to Sir John Rennie, were not adopted. Finally, the spur

at the end of the north pier was removed, and the west pier was completed in 1839, with a bold projecting head, constructed under the direction of Mr. David Logan. The pier is 1,015 feet long, and cost about £120,000. The north pier was finished in 1841; its length is 970 feet, and it cost about £40,000.

### The Dock Works (Plate 4, Fig. 1).

On the completion of the west and north piers, the harbour of Whitehaven became one of the most commodious and convenient in the channel, and many plans were suggested from time to time with the view to obtaining wet dock accommodation at the port. In 1860, Mr. A. M. Rendel advised the construction of a wet dock at the south side, by inclosing a portion of the beach in front of the Wellington pit, and a part of the outer harbour between the old and new quays. But in 1863 he reported in favour of the construction of a dock and other works on the north foreshore. In 1866, Mr. (now Sir John) Coode, M. Inst. C.E., projected the construction of a dock on the foreshore immediately in front of Wellington pit, and to the southward of the west pier, with an entrance within the harbour. It was not, however, until 1871, when the Trustees of the port, town, and harbour obtained the "Whitehaven Dock and Railways Act," that practical steps were taken towards providing wet dock accommodation at the port. These works were designed and carried out by Mr. Brunlees, Vice-President, Inst. C.E., the Author being the Resident Engineer.

In addition to the wet dock and railway, the works included the construction of new piers in the harbour, and the carrying out of other important improvements in connection with the port.

### Site of the Dock and Foundations.

The site of the dock is that originally proposed by the Surveyor to the Trustees, Mr. Stiven. The main area consists of a portion of the north harbour; the remainder, shipbuilding yards and part of the old north wall, being the property of the Earl of Lonsdale. On the north foreshore and in the outer harbour the foundations consisted entirely of sand, upon which a bed of concrete was laid. In the north harbour, below high-water mark, there was a superficial stratum of mud 3 feet thick, underlying which were varying beds of sand and gravel; in some places the sand was coarse and compact, in others treacherous and silty. In the inner or

eastern portion of the site there were thick beds of clean ballast, which was extensively used in the concrete for the new work, and along the southern portion of the site there was a bed of stiff clay; but in no case was concrete dispensed with in the foundations.

### Mode of Carrying on the Work.

Owing to the limited extent of the shipping berths at the north side of the harbour, it was decided that the construction of the new pier, or north wall, should be first proceeded with, so as to afford shipping facilities in lieu of those to be destroyed by the demolition of the old north wall. Accordingly, on the 7th of July, 1872, the first stone of the north wall was laid, and on its being finished the permanent way was put down, and the traffic transferred to it. The demolition of the old wall, then well advanced, was made complete, and the stone from it utilised in the new work. The upholding of the existing facilities for traffic until the new ones were provided necessitated the north harbour being kept open for shipping, which made the work tidal and intermittent in character. During neap tides the foundations of the seaward portion of the work were not accessible, and during low-water spring tides the trenches for the walls had not only to be pumped out, but for the whole working period, about three hours each tide, it was necessary to have the pumps continually running in order to keep the trenches clear. Besides, the porous nature of the strata, and the natural configuration of the site, tended further to increase the amount of pumping necessary, which throughout the work was considerable, and demanded the greatest care and attention in the timbering of the trenches. In many instances, owing to the effect of the tide and the blowing and insinuating nature of the sand, a trench that had been excavated to within a few feet of foundation level would be found, on resuming work at low water, choked up with sand almost to the original surface. The tidal water was not excluded from the area of the dock works until the 1st of April, 1876, and on the 22nd of November following, the wet dock, which was named the Queen's dock, was opened for traffic.

### The North Harbour (Plate 4, Fig. 1).

By the construction of the new pier or north wall (Plate 5, Fig. 2), and the demolition of the old one, the north harbour was so enlarged as to admit vessels of a much larger class. Through a portion of the old wall that was removed, there were three archways or openings,

affording communication between the north shore and the outer harbour. These openings were demolished, and the seaward face of the new pier was constructed in the form of an S, on plan, by the intersection of two reverse curves of nearly equal radii. The waves being reflected from the concave face of this wall towards a common centre, they mutually destroy each other, and this is clearly illustrated during an on-shore gale, when, notwithstanding that the other piers are enveloped in spray, very little sea rises over this wall.

The wall is founded upon sand, upon which was formed a bed of concrete, 19 feet wide and 3 feet thick. When the concrete became set, front, cross and back walls of red sandstone were built upon it. The front wall is 7 feet thick, and the back wall 4 feet thick. The cross walls are 2 feet 6 inches thick, and 6 feet 6 inches apart; the intermediate space or pocket, 5 feet wide, has been filled with concrete—thus making the base of the wall 16 feet in width. The face of the wall has a batter of 1 in 12, and for an average thickness of 3 feet is built of sandstone ashlar set block in course, the stones being squared on the beds and joints, and left rough on the face. The height of the wall is 38 feet 3 inches to the underside of the parapet, and its width gradually diminishes to 11 feet at the top. The parapet is 4 feet 3 inches high, and 3 feet 3 inches thick, built block in course, the beds and joints being fox-dowelled and grouted in cement. Between the parapet and the railway there is a stone causeway 15 inches thick, run in with grout.

During the progress of the work the pockets were kept filled with concrete as nearly level as possible with the masonry; and the support afforded by these monolithic pillars in the heart of the wall tended in no small degree to keep the work intact from the buffeting of the heavy seas to which it was frequently exposed during construction.

The new north wall (Plate 5, Fig. 2) is 50 feet wide at quay level; its outer or exposed wall is built of ashlar block in course, and is surmounted with a parapet. The wall is similar in detail to that already described. It has, in addition, a flight of steps communicating with the north shore, at low water; these steps are built in a projecting counterfort, the exposed face of which is reclined at an angle of 45° with the line of the wall. The inner wall, against which the vessels lie, is similar in construction; but the face, instead of being ashlar block in course, is hammer-dressed rubble laid in broken courses, or "snecked." The coping is of sandstone ashlar, 3 feet wide and 18 inches thick, dowelled at the joints and grouted with cement.

A set of steps is built in the wall in the angle opposite the entrance of the north harbour, for warping purposes; and wrought-iron wall ladders are let into the face of the walls at intervals opposite the tidal berths.

### The Queen's Dock (Plate 4, Fig. 1).

This has an area of 4¼ acres, and is surrounded by quay walls. It is approached from the north harbour, which now forms its basin or vestibule.

The east wall (Plate 4, Figs. 5 and 6) is 583 feet long, and is built to a radius, on plan, of 2 furlongs; its mean height is 40 feet 6 inches, and the concrete base is 16 feet 6 inches wide and 3 feet thick. Upon this, front, back, and cross walls were built of sandstone rubble. The front wall is 6 feet 3 inches, and the back wall 3 feet 6 inches in thickness; the intermediate space or pocket, 4 feet wide, being filled with concrete. The thickness of the wall gradually diminishes from 13 feet 9 inches at the base to 9 feet at the top. The face of the wall is built of snecked rubble, and has a batter of 1 in 12. The coping throughout is of sandstone ashlar, 3 feet wide and 18 inches thick, dowelled with slate 4 inches square, and run in with cement grout. The other walls of the dock are similar in detail, those at the north side being 43 feet high. During the latter period of the work, in order to utilise the stone on the site, the upper portion of some of the walls was built of solid rubble, the concrete pocket being dispensed with, and the thickness of the walls being reduced to 6 feet at the underside of the coping. Weep-holes were carried through the walls at about one-third of their height from the base, and 50 feet apart. These vents relieved the walls of hydrostatic pressure during the progress of the work, and they were carefully closed before the water was admitted to the dock.

### The Dock Entrance (Plate 4, Figs. 2, 3, and 4).

The dock entrance is 50 feet wide at the level of the coping, and its floor is 80 feet in length. The foundation consists of sand, upon which was formed a bed of concrete, varying in thickness from 5 feet under the inverts to 8 feet under the sill. The sill, inverts, and gate floor are of sandstone ashlar, and the pivot stones and hollow quoins are of granite. The inverts have a versed sine of 4 feet 5 inches, and are 3 feet 6 inches thick. The sill is flat, but the back and joints radiate on plan. The square quoins and

chain-hole quoins are of sandstone ashlar; within the inner chain-holes there is a cast-iron frame fitted with friction rollers to guide the gate-chains. The pier-heads are formed by the intersection of two reverse curves on plan, each 15 feet radius at the level of the coping. The side walls are built of snecked rubble, and, with the exception of the gate-recesses, have a batter of 1 in 12 on the face. The sill is 1 foot above the dock floor, and 21 feet below high water of ordinary spring tides. Across each end of the floor there is a row of 6-inch birds-mouth sheeting driven 12 feet.

### The West Quay (Plate 4, Figs. 7 and 8).

This forms the barrier, 80 feet wide, between the north harbour and the Queen's dock. Owing to the treacherous nature of the strata, its construction was carried on under circumstances of greater difficulty than any other portion of the work. A length of about 100 feet of the central portion of the quay crosses an old channel of a land stream called "Bransty Beck." When a portion of the outer wall immediately over this channel had been carried up about halfway to coping level, it showed unmistakable signs of settlement and of lateral movement. To avoid the delay and expense that would attend the removal of this portion of the wall by tidework, it was decided to remove only a central piece, sufficient for the construction of a pier 15 feet wide on the face. This was done, and twenty-five whole-balk piles, 14 feet long, were driven in as nearly equidistant apart as possible. Portland cement concrete was then filled in and rammed round the heads of the piles for a depth of 1 foot. When this had set, the pile heads were sawn off to a uniform level, and tied together laterally with cap-walings, 12 inches wide by 6 inches thick, spiked down to each pile head. The concreting was then proceeded with until a bed 4 feet thick was formed, upon which the central pier was built. An abutment at each end of the wall was built in a similar manner, and an arch of 44 feet span and 8 feet rise was turned over the old work on each side of the central pier. The face of the arches is of sandstone ashlar, and the back of six 4½-inch rings of brick in cement. The new and old work was bonded and grouted together, and the wall carried up and the coping laid.

Birds-mouth pitch-pine sheeting, 12 inches wide by 6 inches thick and 12 feet long, was driven in front of the old work; and the space between the sheeting and the toe of the wall was cleaned out and filled in with concrete. The foundation piling was con-

tinued for a short distance past each abutment, and a portion of the inner or dock wall, immediately opposite where the settlement occurred in the outer wall, was also piled. The piles were shod, and driven by a steam pile driver, the monkey weighing 21 cwt. Those under the centre pier of the arches carry a load of 47 tons each, or 17 cwt. per superficial foot of pile. But under the walls in general, where the ground was very soft, each pile was driven until it ceased moving more than $\frac{1}{2}$ inch by a blow from the monkey falling 10 feet, and the load upon the piles does not exceed 10 cwt. per square foot of frictional surface of pile.

The concrete consisted of 1 measure of the best Portland cement and 6 measures of ballast and broken stone. In the concrete for the pockets in the walls, above the level of high-water mark, ground lias lime was substituted for Portland cement. The mortar was made from Aberthaw pebbles, burned in a kiln upon the works, and mixed in a mill in the proportion of 2 of sand to 1 of lime. The beds and joints, in the face of the walls, were raked out and pointed with cement mortar in the proportion of 1 of sand to 1 of Portland cement.

### The Gates (Plate 5, Fig. 3).

These are of pitch pine, with the exception of the heel and mitre posts, which are of greenheart. Their height from the roller-path to the gangway is 35 feet, and when closed their ratio of rise to the span is 1 to 5. The ribs are straight next the sill, and curved on the pressure side; they are each formed of two balks placed side by side, bolted and dowelled together, and tenoned into the heel and mitre-post. Their depth is 12 inches and constant throughout, the thickness in the centre being 2 feet 2 inches, diminishing to 1 foot $4\frac{1}{2}$ inches at the ends. The planking is of pitch pine 3 inches thick, feathered, caulked, and secured to the ribs by treenails $1\frac{1}{4}$ inch in diameter and 15 inches long. A cast-iron cup, fitted with a gun-metal disc, is let into the bottom of each heel-post. The disc bears upon a cast-iron pivot 9 inches in diameter, let into and bolted down to the granite heel-post stone. The radius of the bearing-surface of the pivot is 9 inches and that of the disc 12 inches. The top hollow quoin consists of a cast-iron block formed to clip the heel-post in a similar manner to the granite quoins, and tied into the side wall by wrought-iron anchor-straps. The heel-post head is hooped and held in position by a wrought-iron strap screwed at each end, the nuts clamping the inside of the anchor casting. Each gate is fitted with a cast-iron

roller, bearing upon a cast-iron roller-path of 26-feet radius. The weight upon the roller is adjusted by a screw, working in a fixed nut attached to the gate in a casting above high-water mark.

The gates are surmounted with a gangway 4 feet wide, supported on saddle castings bolted to the top rib. On each side of the gangway there are movable standards and guard chains. Two sluices are fitted to each gate, for adjusting the level of the water in the dock, and for scouring the apron and keeping the channel clear in the vicinity of the entrance.

The opening or closing of one of the gates is effected by a chain being wound round a horizontal barrel, worked by a pinion fitted with a capstan-head, and fixed in a chamber just below quay level. When the capstan bars are withdrawn, the chamber is covered with a light chequer plate let in flush with the surface. The pier heads are thus free from obstruction; and in the event of hydraulic power being adopted at the harbour, it could be applied to the gate machines without much inconvenience. The maximum stress in the direction of each gate during spring tides is 260 tons, or about 230 lbs. per square inch of rib section. A capstan is erected on each side of the pier head, and also a watch-house for the dock gatemen and piermaster.

### Facilities for Traffic.

On the north side of the Queen's dock (Plate 4, Fig. 1) abuts the terminus of the London and North Western railway, in connection with which and the Furness railway sidings have been laid round the several quays. There are also sidings in connection with the collieries and iron-works in the neighbourhood. Coal drops, and other appliances for facilitating traffic, have been erected; and at the south side of the dock, convenient to the principal street approach to the harbour, offices have been erected for the dock officials, with a tower and look-out commanding a complete view of the harbour and offing.

### Embankment and Railway (Plate 5, Fig. 4).

In order to connect the north and south sides of the harbour for railway traffic, an embankment was made across the beach in the inner harbour. This embankment forms a quay with a minimum width of 50 feet, and its seaward face is protected with stone pitching, from 12 to 15 inches thick, laid dry upon a bed of shingle with a slope of $1\frac{1}{2}$ to 1. Between the shingle and the filling there

is a layer of clay puddle from 9 to 12 inches thick, the whole finishing with an ashlar stone coping, set on edge and standing 18 inches above the ground.

The filling necessary to form this embankment was obtained from the excavation for the dock walls, and upon it a through line of permanent way with a loop-siding has been laid. The permanent way consists of flat-bottomed steel rails, weighing 76 lbs. to the yard, laid upon creosoted sleepers placed 2 feet apart, except at each rail joint, where their distance apart is only 15 inches.

### The Swing Bridge (Plate 5, Figs. 5, 6, and 7).

At the south end of the embankment there is a patent slip, which had to be crossed by the railway in order to make the connection of the two sides of the harbour complete for traffic. This was effected by a swing bridge, for which foundations had to be constructed. The main girders of the bridge are 62 feet long, and 13 feet 3 inches apart from centre to centre; their depth in the plane of the bridge-pivot is 5 feet, and the breadth of the flanges is 15 inches. As the bridge is subject to the greatest fatigue when open, the girders gradually diminish in depth and flange area towards the end of their long arm. Owing to the limited area of the site for the tail end of the bridge, the length of its long arm to that of its short arm had to be made in the ratio of about 3 to 1; and, in consequence, a considerable amount of balance weight was necessary at the end of the short arm. The tail end of the bridge was, therefore, finished with a cast-iron curb weighing 5½ tons, and the remainder of the balance weights are carried in a wrought-iron chamber suspended at the tail end of the main girders. The web-plates of the main girders are ¼ inch thick, and the joints are covered with T-iron and angle-iron stiffeners. The cross girders, which occur every 3 feet, are 12 inches deep; the web is formed of ¼-inch plate; and the flanges of a couple of angle irons, 3 inches by 3 inches by ½ inch, are riveted at the ends to the main girders. These cross girders carry two pitch pine longitudinals, upon which the permanent way is laid. Between each rail and the main girder packing pieces are laid upon the cross girders to receive the flooring. The flooring is of pitch pine 2 inches thick, laid longitudinally with open joints, each plank breaking joint with the other. The turn-table, whose mean diameter is 13 feet 3 inches, consists of an upper tramway bolted to the main girders, and a lower tramway bolted to the

masonry forming the floor of the bridge-pit. The faces of these tramways are turned to a true cone, having its apex upon the axis of the turn-table.

Between the tramways there is a wrought-iron live ring fitted with twelve cast-iron rollers, bushed with brass and revolving freely upon their spindles. The spindles or radial rods are screwed at the ends, and have nuts so as to clamp both the live ring and a cast-iron wheel revolving in a horizontal plane upon a nave of the pivot casting; the radial rods are so formed that they can be readily withdrawn in case of accident or for repairs.

The centre pivot of steel, 6 inches in diameter, is keyed into a casting bolted down to the masonry. On the top of the pivot rests a steel disc, 9 inches square and 3 inches thick, let into the centre of the top tram casting, and held in position by a wrought-iron plate with six 1½-inch screw bolts. The distribution of the load between the pivot and the rollers is adjusted by the tightening or slacking of these screw-bolts. When the bridge is closed, the end of its long arm is locked and supported by cast-iron wedges fitted to the underside of the main girders, and resting upon cast-iron sole plates bolted to the pier. The wedges slide in and out of position on a fixed screw worked by mitre gear on the bridge. The turning gear is fitted to the tail end of the bridge, and has a purchase of 25 to 1 at the rack. The rack has a radius of 15 feet 9 inches, and is bolted to the face of the breast wall of the bridge pit.

The total weight of the bridge and turn-table, including 30 tons of balance weights, is 70 tons. When completed, it was tested by being opened and closed with a weight of 5 cwt. at the extreme end of its long arm. The flange strain was then 4 tons per square inch in the plane of the pivot.

All the rubbing surfaces of the moving parts can be readily lubricated, and the bridge can be opened and closed with ease, through an arc of 95°, in a minute and a half, by one man at the turning gear.

### New Timber Slip, etc. (Plate 4, Fig. 1).

To make the railway connection complete between the north and south sides of the harbour, it was also necessary to remove the old timber slip, and to construct a new one farther seaward. The extension of Pow Beck and the construction of a new quay frontage across the end of the custom-house dock were also effected at the same time.

### Cost of the Works.

The total cost of the works, namely, the Queen's dock, harbour extension, and railway, and all other improvements, was about £100,000.

The contractor for the dock works was Mr. Joseph Phillips, Assoc. Inst. C.E., but their completion devolved upon Mr. Thomas Parry. The contractors for the swing bridge were Messrs. Fletcher, Jennings, and Co., of Whitehaven; and the contractor for the harbour railway connection work in general was Mr. John Thomson, Assoc. Inst. C.E.

This communication is accompanied by a series of diagrams and small scale drawings, from which latter Plates 4 and 5 have been engraved.

Mr. ABERNETHY, Vice-President, desired to call attention to one or two points in the Paper involving important questions of hydraulic engineering science. Before doing so he wished to remark that Mr. Mackenzie, in his Paper, had scarcely done justice to the authorities of the Port of Bristol, who, when the subject of ocean navigation became an important question, constructed docks at very great cost under the direction of the late Mr. Brunel for the accommodation particularly of the required class of steamers; and certainly at that time those docks were in advance generally of similar works in other parts of the kingdom.

The Paper by Mr. Mackenzie was somewhat exceptional, inasmuch as he had not only detailed all the various operations connected with the construction of the works at Avonmouth dock; but he had also described to a considerable extent the failures that had occurred, not simply during the construction of the works, but from their completion to the present time. As he had himself been engaged as far back as 1864 in promoting a Bill in Parliament for those works, and had subsequently visited the site at various periods, he could bear testimony to the great difficulty attendant upon the construction of docks on such a site, arising from the treacherous nature of the alluvial deposit overlying the bed of the sea, which was liable to extensive slips on any attempt at excavating, and also from the upward pressure of water from the sand beneath the superincumbent strata of light clay. He knew, from experience in constructing such works upon a somewhat similar site, that a great amount of attention and care was required, and that, with all the precautions which prudence and foresight could dictate, accidents would occur. He thought it was due to the Engineer-in-Chief, Mr. Brunlees, to say that the extensive works which he had successfully constructed would easily permit him to acknowledge a few failures; and the younger members of the Institution would derive more benefit from a study of the causes of those failures than from the narration of the construction of perfectly successful works. He regretted that Mr. Brunlees was not present, owing to a severe domestic affliction. At the commencement of the Paper reference was made to various projects for the construction of docks in the river Avon; and among others he had enumerated those for the canalisation—or, as he termed it, the dockising—of the river. As projects of that character were entertained by professional men even up to the present day, he took this opportunity of expressing the strong opinion which he had entertained for many years of the utter fallacy of such works; and in doing so he would use the example of the river Avon as bearing out the conclusions at which he had

arrived. A reference to the chart of the Bristol Channel showed that, at the mouth of that river, a deep-water anchorage existed known by the name of King-road. That deep water was maintained by the powerful tidal action of the river Severn running round the concave shore between Passage and Portishead; and the navigable channel leading across the foreshore from King-road to the river Avon, which formed the approach to Bristol, was maintained solely by the tidal column passing up and down the bed of the river from Bristol to the sea. Mr. Mackenzie had stated that the Avon was the muddiest river in the kingdom, depositing as much as 15 inches per month of detritus, and he had also pointed out that the original navigable channel round the north of Dumball Island had been entirely obliterated. He recollected that channel when it was the main channel of the river Avon. Mr. Mackenzie stated that various reasons had been assigned for that result. To his mind it was exceedingly simple. The tidal flow of the Avon had been for many years gradually seeking a more direct channel into King-road, and as the channel now existing was slowly formed the old channel round the north of Dumball Island silted up, until it was entirely obliterated. Now, suppose that, for the purpose of the canalisation or dockising of the river, a weir or dam were thrown across the river Avon, to the exclusion of any material volume of the tidal water ebbing and flowing, the same result would ensue with regard to the existing channel as had taken place in the former channel round Dumball Island, namely, it would gradually silt up and become obliterated. Many important ports were situated upon tidal rivers, and he was strongly of opinion that every attempt to diminish the tidal volume of those rivers should be resisted to the utmost. He would not comment upon the various failures in the works mentioned, because the causes of the failures and the remedies applied had been clearly set forth in the Paper itself.

With reference to Mr. Salmond's Paper on Belfast Harbour, the result of dredging and draining the river Lagan had been simply beneficial, as it had been in the case of the Tyne, the Wear, and other rivers. The cause of the failure of the walls at Belfast was obvious, and it would have been more surprising if they had stood than it was that they had fallen.

In the Paper on Whitehaven Harbour, by Mr. Williams, it was pointed out that the combined action of the construction of the west pier in the form of a solid groyne from the sandy foreshore, and also the pier to the northward, had been to advance the low-water line seaward, and that the obstruction of the littoral currents

which carried the sand in suspension had caused a deposit on each side of the piers, even to the extremities, so that the entrance to the harbour had silted up. The same result had followed the construction of similar works—in the case of the Suez Canal at Port Said, which had to be kept open by dredging, and also at the harbours of Calais and Boulogne. On looking at a chart of the English Channel and the North Sea it would be seen that northward of Calais, along the coast of Belgium and Holland, the foreshore consisted of sand, in the channel, easily disturbed by the littoral currents which had determined the normal line of low water; and seaward of that normal line of low water existed numerous sandbanks. The effect of the projection of the piers at Calais and Boulogne had been to advance the low-water line beyond the original normal line by the accumulation of sand, so that at present at Calais Harbour there existed less depth of water in the channel entrance than within the harbour; and the same result had taken place at Boulogne. In the face of these facts, at the present time an extensive harbour was about to be constructed at Boulogne, by the projection of piers still farther seaward; not parallel piers, but enclosing a large space within them. It was argued that at the extremity of these new piers a powerful littoral current now existed, which would remove any deposit that might take place; but he had no doubt, having regard to what had occurred at Calais, Boulogne, Whitehaven, Port Said, and numerous other harbours, that the effect would be the gradual advancement of the low-water line seaward, and the accumulation of sand at the extremity of the new piers; and with this addition, that by enclosing a large area within there would be a great accumulation, which at present was removed within the harbour of Boulogne by sluicing from the upper part of it by the action of the current between the parallel piers. He saw no reason to doubt that that would be the eventual result, because the advancement of the low-water line and the gradual shoaling, consequent upon the construction of the works, would destroy the effect of the littoral current at present existing, and would, in his opinion, result in the entire failure of the harbour as a deep-water harbour on the French coast. It was of vast importance that a deep-water harbour should be provided on the coast of France, because he was of opinion that "the horrors of the Channel passage" could not be ameliorated in any sensible degree by other means; certainly not by the construction of naval architectural abortions. There were two salient subjects to which he hoped the discussion would be directed: first, the effect which would follow the canalisation of navigable rivers;

and, secondly, the result of the construction of harbours upon sandy foreshores by the projection of solid piers or groynes at right angles to the foreshore subject to littoral currents.

Mr. ALFRED GILES, M.P., agreed with Mr. Abernethy as to the probable effect of running out long piers beyond low-water mark on a sandy shore. He conceived they could have no other ultimate effect than that of acting as groynes, against which the sand would accumulate. The history of Avonmouth dock reminded him of the early history of Southampton dock, which was begun in 1839 and opened in 1843. It extended over 16 acres, and the difficulties to be contended with were perhaps as great as those in the Avonmouth dock. The Nelson column was being erected at the same time, and the progress of the two works was so slow as to elicit the remark from *Punch* that the boy who was working on the column was taken off to help the other boy at Southampton docks. But if the progress of the Southampton docks was so slow, that of Avonmouth dock had been much slower, eight years and a half being occupied in its construction. The Bill was passed in 1864, but, owing to financial and other difficulties, the work was not commenced till 1868, and the dock was opened in 1877. Certainly eight years and a half seemed a long time, but of course it was impossible to measure financial difficulties. The lock, which was 454 feet long, had been very wisely constructed to take in the largest class of steamers. It was only the other day that a steamer was launched for the Cunard line 450 feet in length. If, however, a vessel 450 feet in length ever required to use the Avonmouth dock she would have to come out stern foremost. Looking forward to the construction of vessels of that large class, it would, he thought, be desirable to make a place where they could turn round instead of going out stern foremost into the sea, where the engines would be of little avail, in the event of a ship getting into trouble. He desired to thank Mr. Mackenzie for the way in which he had described the shortcomings in the construction of the dock, because it required a great deal more moral courage on the part of an engineer to describe a failure than to describe a success, and much more was to be learned from failures than from successes. The question of dock walls was one in which he had a large and painful experience, and he could only repeat what he had said many years ago, that the quality of a dock wall was of little consequence compared with the quantity. It wanted weight to resist lateral pressure, and he maintained that a dock wall ought to be sufficiently strong, not only to hold any amount of any kind of backing put against it, but

to carry a head of water equal to its height if it were left dry on the other side. He admitted that the walls of the Avonmouth dock were not capable of doing that. He thought the section as a section was amply strong, and that the fault was (as in the case of most dock walls) in the foundation. The Paper stated that the width was 22 feet 6 inches. He had lately put up a wall, and had made the base, which was upon gravel, 25 feet wide. It was 40 feet above the bottom of the tide-way to the coping. That wall moved, not seriously, but enough to show that a base of 25 feet was not sufficient for a wall of that height. The wall, when founded upon a layer of 5 or 6 feet of gravel, did not move, but where the clay was within 3 feet of the gravel, there was sufficient weight upon the gravel to cause the clay underneath to move, and there was a slide forward of some few inches, enough to destroy the straight line, although not enough to need repair, or to be any disadvantage, except in appearance. He thought that, in the case of most dock walls, engineers erred in not making the base wide enough. It would be seen that the section of the lock wall was pretty nearly of the same strength as the section of the dock wall. But what was the difference? It had an invert in front of it, and the dock chamber never slid. He maintained that, if a mass of concrete were put in front of the wall, supposing it to be 40 feet high with a base of 30 feet, the base being made as a toe in front, the wall would never move. Engineers generally erred in not putting sufficient toe to the walls. Then there was another point often lost sight of. The ground in the foundations as seen before the water was let in, was probably dry and hard, but consideration should be paid to the change that would take place after it had been saturated with water for many years. Such a change would often cause a wall to slide forward. He believed that had occurred at Barrow, where a wall which had been standing for many years all at once slid into the entrance. The same kind of trouble had been experienced with the walls at Belfast. He did not approve of the means usually adopted in repairing damage of that sort, by putting a huge counterfort behind a solid wall. He believed that, if the water were let out of the dock, the wall would separate from the counterfort and fall forward. He had tried that plan, and had found it fail. The only thing he had found of use was a buttress in front of the wall, and not behind. Where the wall was just upon the balance, instead of attempting to strengthen it by an expensive and doubtful method, he thought the cheapest and simplest way was to take out a certain amount of soil from the back of the wall, to lessen the weight that the wall had to carry,

and to cover over the space so relieved by a timber platform. There was nothing nicer to work on than a timber platform, although in such a situation it became little better than a fungus-bed, and the timber required renewing every ten or twelve years. That was the experience at Southampton. Many of the walls were backed with timber. The walls put up nearly forty years ago were not able to bear the weight when loaded up to the coping height, but by excavating 10 or 12 feet deep for a space of 30 feet wide from the back of the wall, and covering the space with a timber platform, they stood remarkably well. He had seen the temporary dam at Avonmouth when the gates were being finished, and he did not think he had ever seen any dam more perfect, or better adapted to its purpose. With regard to the gates, he confessed that he was a little staggered to hear of two rollers being used, particularly when he heard that the deposit in the water was something like 15 feet a year. With that extent of deposit the least contact there was with the bottom the better, and he should be very much afraid that before long some trouble would be experienced in working the gates. He had always understood that the dock was to have been filled with fresh water for the purpose of avoiding the risk of deposit from the Avon, but he believed there was no provision for that, the water now used being out of the channel. It was a serious question for those interested in the dock to know how it was to be kept open, or how the lock was to be worked after a short time when there was so large a deposit. The statement as to the cost of the works had struck him as being much in favour of granite; Forest of Dean stone at 3*s.* 6*d.* per cubic foot was used instead of granite, which could be got, ready for setting, at 3*s.* He was now using granite at that price; the hollow quoins cost 4*s.* 6*d.*, but the ordinary blocks only 3*s.* or 2*s.* 9*d.* per cubic foot. He could say nothing with regard to the Belfast Paper, because there were no plans to show the general improvements in the harbour; but with regard to the failure of the walls there, the same remarks might apply as to failures elsewhere.

Mr. WALTER R. BROWNE hoped he might be excused in making a few remarks on the subject of the Avonmouth docks, because, during part of the time of their construction, he was engaged on the works which, as Mr. Mackenzie had mentioned, were being carried out at Bristol itself for the improvement of the existing docks, at the expense of the Corporation, and under the superintendence of Mr. Thomas Howard; he had therefore had the opportunity of seeing a good deal of similar work, and of meeting the same sort of difficulties as those encountered by the constructors

of the Avonmouth dock. He would, however, confine his observations to three points. First, the slip of the wall, on which Mr. Giles had already commented. He had seen the first slip of the western wall, shown in Plate 1, Fig. 10, a few days after it had happened, and he was certainly very much impressed by the sight. As far as he could remember, and judging by a rough sketch he had taken at the time, Fig. 10 did not exactly represent the way in which the wall had gone out. The central part, which had gone the farthest forward, was much longer than appeared in the diagram, which represented two wings meeting at an apex in the centre. His sketch showed a flat part for the greatest portion of the length which had given way, with two returned portions much shorter than in the diagram, and inclined at a sharper angle, uniting it on each side to the part which had not moved. It was impressive to see how at the junction of those inclined parts with the straight parts the solid blocks of Forest of Dean stone had been cracked through like so many pebbles, and also how the whole wall had been moved bodily forward by the pressure behind it, a distance of 12 or 15 feet, leaving a huge pit at the back where the made ground thrown in for the backing had sunk down. One point confirmed (as his own experience had confirmed) the remark of Mr. Giles as to the necessity of a better concrete footing to the wall. At each end of the central part the concrete footing had been actually shorn through, or broken right across by the weight of the wall which had sunk down for some distance, carrying the concrete with it. That appeared to point to the fact that the concrete was too thin to start with, as well as not being supported properly at the bottom, so that the weight of the wall had been sufficient fairly to break it through. Although no doubt the failure at that spot might have been due to some local cause such as Mr. Mackenzie had mentioned, the lesson which ought to be drawn from it was the extreme danger of building a wall upon clay which there was reason to suppose was originally laid down at the bottom of a tidal estuary, as was doubtless the case with the clay at Avonmouth. The same clay was met with throughout the tidal course of the Avon. When first dug down upon, while dry, it looked sound and firm, and there was no reason for surprise that engineers, when dealing with it for the first time, should think that they had a good foundation; but the moment water settled upon it the clay melted like sugar; it ran away into slurry, was squeezed out in all directions, and was absolutely useless for any purposes of foundation. In fact, it had been wet mud originally, and when wet it returned to mud again.

Mr. Giles had stated so exactly what he should himself wish to say as to the other peculiarities of the wall, that he would pass on to the second point—that of the lock gates. He thought it must be admitted that the designers of the Avonmouth docks took a bold step when they resolved to make gates for a lock of that width of timber. Of course, he was aware that the great gates of the 100 feet lock at Liverpool were of timber, and that might be quoted as a precedent showing that it was feasible to make timber gates for a lock of that span; but it should be remembered that at Liverpool the rise of the tide was much smaller than at Bristol, and consequently the pressure to which those gates were exposed was but a fraction of that at Avonmouth. Then on examining, in the Paper, the principles and calculations by which the gates were constructed, he found himself confronted by the well-known formula $t = pr$. Some years ago he had read a Paper before the Institution on the strength of lock gates,[1] when he brought forward some reasons for thinking that this formula was not so universally applicable as generally supposed. As the point had now been alluded to again, he might be allowed to make one observation respecting it. The formula was only rigidly and accurately true in the case of an indefinitely thin cylinder of perfectly homogeneous material under an uniform external pressure normal to the surface. Now, before applying the formula in practice, it seemed desirable to arrive at least at some understanding as to how far the structure answered to, or differed from, the ideal case for which the formula was rigidly true. Certainly in the structure in question the divergency from that ideal was serious, and he was quite sure that the formula could not be made to fit into it by the simple device of shaping the outside line of the gate to the exact form of an arc of a circle. It was obvious that the line which required to be circular—if there was any magic in the circular form—was not the outside line, but the line which passed through the centre of pressure of all the cross-sections of the gate, and which would correspond to the ideal line of the ideal cylinder. Where that line passed, even in the iron gates, where construction was comparatively simple, was, as he could personally testify, by no means easy to determine. Where it passed in a gate built up of thirty or forty pieces of timber, he defied any gentleman to determine, either by practical or theoretical considerations. The outside line, in fact, had practically no pressure upon it, because, in almost all cases, it was cut away at the mitre in order to insure the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxi., p. 317.

gate's shutting properly, and consequently, whatever virtue there was in the formula, it could not apply to that case. He did not deny that the gates described might be quite sufficient for their purpose, but they certainly were not proved to be sufficient by the simple fact that they gave a sufficient factor of safety when tested by the formula $t = pr$. He agreed with Mr. Giles that the use of a second roller, especially with no means of adjusting it, was a somewhat doubtful measure, since with two rollers it was almost impossible to tell how a gate would bear; but as to keeping the lock clear, he did not anticipate any difficulty as long as proper attention was paid to scouring it out at low-water spring tide. That plan had been in constant use at Bristol with satisfactory results. He desired to point out that although the gates might have worked well hitherto, that was no guarantee that they would so work always. Of course the first result of letting in water upon a timber gate was to swell up all the joints, to bring everything together, and so to make the gate for the time being firmer to resist compression; and that would be the case as long as the timbers continued sound. But whenever the natural process of decay, to which all timber structures were exposed (especially a structure like a lock gate, subjected perpetually to alternate wetting and drying), began to act, it was doubtful whether considerable expense would not be required to keep the gates watertight and secure.

He would now pass to the third question—that of the foundations—and although his remarks might seem to be more of geological than engineering interest, they had an important practical bearing on what Mr. Abernethy had stated. During the works at Bristol it was necessary to sink for the formation of a large lock at Cumberland basin, the sills of which were about 3 feet higher than those of Avonmouth dock. He had a note of the section of ground passed through in sinking for the foundations: 12 feet of brown clay; 25 feet of blue silt apparently much the same as the silt that now formed on the shores of the Avon; 1 foot of mixed sand and clay, in which were numerous oak-trees, horns and bones of animals, and other remains; 6 feet of gravel and sand; and then new red sandstone rock. The bed of gravel and sand lying above the new red sandstone rock was perfectly clean, and the water ran out as clear as possible, but it was brackish. On looking over the pebbles contained in it he found specimens of almost all the numerous formations which the river Avon cut through in its course to the sea; proving conclusively that the gravel represented an old bed of the river, which, at some time or

other, had cut its way transversely across the site of the new lock, and had left a deposit of silt on the top of what had once been a low-water channel. He had been much puzzled to account for the gravel, which apparently had been close to the bottom of the river, being so clean, and had suggested that it was due to the fact that the Avon was not at that time a tidal river, and that the celebrated gorge at Clifton could not then have been cut down to its present depth. Two things had shown him that he was wrong in that suggestion. First, the fact that Mr. Mackenzie had found the same bed of gravel, at about the same depth, or a little lower, at Avonmouth, where clearly no such cause could have existed. Secondly, the curious experience obtained a year or two later, when, in order to straighten the course of the Avon a little way below Bristol, a dredger was sent out to dredge in the low-water channel of the river. She commenced work almost immediately below the Clifton suspension bridge. Many Members must have looked down from the bridge, and would remember what an extremely muddy stream they beheld; nevertheless, the spoil which the dredger brought up consisted of gravel and sand and blocks of stone so clean that it was taken on shore, and merely required the breaking up of the large blocks of stone, with the addition of a proper quantity of lime, to make it into concrete; some thousands of tons were actually made in that way. That showed clearly that the bottom of the low-water channel of a tidal river could be kept clear by the action of low water; whereas the sides, which were exposed to the tidal flow, were always many feet deep in mud. That brought him to the question of tidal scour, a very important point which it was most desirable to clear up. He was not expressing his own opinion merely; he was supported by that of engineers who had large experience, certainly in the cases of the Avon and the Severn. His view was, that the tidal flow up and down a river, so far as the river was concerned, was an absolute and unmitigated evil; that it was simply an engine for carrying a quantity of mud up the river, and leaving it there, to be disposed of by some other agency, that agency being in ordinary cases the scour of the low-water channel during the period of low water. It would take too long to go through all the reasons on which he based that opinion; but they were not mere ideas, they were actual facts. With respect to the points raised by Mr. Abernethy, two questions should be considered before adopting the view he had expressed. It had been stated that if the Avon were turned into a ship canal, by setting up gates near the mouth, the present Swash channel would silt up, as the North channel had

silted up. Now in the first place, did Mr. Abernethy suppose that the waters of the river Avon would in that case cease to find their way into the sea? Or, if not, through what channel would they find their way? And in the next place, did he forget that, supposing the Avon to be dockised in the way suggested, there would be at every low tide a head of water of, on an average, 30 feet available for scouring? And could it be denied that the scouring power obtained by the possession of an unlimited head of water of that height would give a means of clearing out the channel, compared with which any tidal flow became a matter of the utmost insignificance? For those reasons he strongly held the opinion that there had been no greater mistake than the idea that the tidal action of rivers was a thing to be regarded as of supreme importance, and he hoped that his remarks might lead to a full discussion of the subject.

Mr. REDMAN wished to direct attention to a point affecting materially the difficulty of construction upon relative sites, and also the proportionate cost of such works. No three examples could have been selected to illustrate more clearly the great variation in the tidal rise within the British seas. In the first case there was a maximum rise of tide exceeding 40 feet at equinoctial spring tides; in the second example, at Belfast, there was but one-third or one-fourth of that rise; and in the third example there was the very considerable rise of 23 feet. The causes of the great rise of the tide at Portishead were well known. In Morecambe Bay, the confluence of the two waves passing round the north and south of Ireland raised the great head of tidal water at Whitehaven. Belfast was situated in the neutral zone of water between that place and the Isle of Man. At Portishead, where the rise at spring tides was 39 feet or 40 feet, the rise at neaps was only 20 feet. At Whitehaven, where the rise at spring tides was 26 feet, the rise at neaps was only 13 feet. At Belfast, however, where the rise was 11 feet at spring tides, the difference between the rise at springs and neaps was only 18 inches; and on the eastern coast, in the estuary of the Wash, where there was a rise at spring-tides of 23 feet (very much in excess of the normal rise of the adjacent coast), the rise at neaps was only 9 feet; showing plainly that the high spring tides were more influenced by the embayments into which the tide was led than were the neap tides. With regard to Belfast, it appeared that after all the most eminent engineers of the day—the Rennies, Telford, and others—had been consulted, the governing authorities had had the sagacity to adopt the later advice of the school in which he had been brought up—

that of Mr. James Walker—not to canalise the channel leading up to Belfast, but to improve the natural tidal channel up to the port; and the endeavour of their successors had been to improve the artificial dredged channels by making them straighter seaward. As to the failures of the works which had taken place, the descriptions showed (as numerous instances recorded in the Proceedings of the Institution showed) that they arose mainly from the want of depth in the base of the wall, and in many cases from the careless way in which the backing had been put in.[1]

Mr. F. E. DUCKHAM said it was stated in Mr. Mackenzie's Paper that there was a batter on the side of the lock of 6 feet 3 inches. He presumed it meant on each side; and in that case the lock would be 12 feet 6 inches less at the bottom than at the top. There might be an advantage in that, so far as the construction of the wall was concerned, but there was an undoubted disadvantage in docking and undocking ships. With water at the higher level there was plenty of room in the lock for two ordinary vessels; but when the water was lowered, or when one vessel was going in and another going out the bilges would possibly catch on the wall below, and the vessels be jammed. Some twenty years ago,

---

[1] He begged permission to cite the following extracts in respect to Folkestone and Dover harbours:—"The modern projection of the pier at Folkestone acts as a large groyne, and has promoted the deposit to windward of a vast mound, by which that town has benefited; the area upon which the Pavilion stands being thus reclaimed. Formerly, before the erection of this work, the shingle travelled eastward, and filled the harbour; and forty years back it was the daily task of the fishermen to dig a channel before their boats could leave the harbour.

"The Admiralty pier at Dover also acts as a huge groyne, and the resultant effects upon the shore, on either side, are very remarkable. It was supposed, when first designed, as the west arm of the contemplated enclosure of the bay, that it would arrest the shingle westward and prevent it travelling into the bay, which had been for years the source of so much trouble and expenditure at the entrance to the old harbour; but since the erection of the Folkestone pier there has been an almost entire absence of shingle travelling from the west, and the shore eastward past the South Foreland to St. Margaret's Bay has suffered correspondingly; for where a few years back was a broad belt of shingle and a roadway, the sea now washes the base of the cliffs. It has, however, promoted a deposit of lighter material and sand along the shore on a great scale. To the westward the foreshore has grown out and risen in height to the extent of from 3 to 6 feet, and at least a million of cube yards have thus accumulated. To the eastward a spit has grown out, containing about 400,000 cube yards, tailing into the centre of the bay, of an average height of 4 feet; but in places against the pier there has been a vertical accumulation of 15 feet."—'Chatham Lectures,' 1875–76, p. 15.

"The recent degradation of the shore from St. Margaret's to Dover is almost as remarkable as in the district now under notice."—Report on Sandown Castle, &c., for War Department, 20th December, 1856.

two vessels were totally wrecked at the entrance of the East India dock from that cause. Other locks had been made with vertical sides, and he thought that that was a safer way of constructing them. There was another evil in connection with a battering side to a lock. The gate had a vertical face, and when a vessel was passing through, the bow would be likely to drop into the recess made by the vertical face of the gate, and the lower part of the bow would then catch against the projection caused by the sloping side of the lock. At Avonmouth the face of the lock gate was hollow on plan; but at Whitehaven it was flat and curved at the back, in other words, plano-convex. There was a great advantage in that configuration. It was far preferable to have a straight and plain face through the lock, so that when the gates were open there were no projections nor recesses of any sort. As to the gates being on two rollers, he considered that, although the arrangement arose from a miscalculation, it was a very good one. It seemed like putting the gate on three legs and giving it an amount of rigidity which would have been wanting had the centre of gravity been over the centre of support. With regard to the silting up of the lock, his experience confirmed the statement that the scouring caused by the adjustment of the lock water level was sufficient to keep the roller paths clear. It would be observed that there was some concrete with ashlar facing shown in the section of Avonmouth dock. One of the largest docks in the world was now being made on the Thames with concrete walls throughout. If concrete was good enough for upper work it was good enough for lower work without any ashlar facing. Mr. Mackenzie had not said anything about the hydraulic machinery, except that the cost had been £18,000. It would be interesting to know what kind of machinery was used. It was stated in the Paper on Whitehaven harbour that the bridge was tested by placing 5 cwt. upon it. That probably was a mistake for 5 tons. The difference in the weight of the bridge in a dry summer and in winter, when the timbers were saturated and perhaps laden with snow, would fully represent 5 cwt. Moreover, notwithstanding prohibitory notices people would often rush upon the bridge when in motion, twenty or thirty at a time, and their weight would greatly exceed 5 cwt.

Mr. W. PARKES said that Mr. Abernethy had called special attention to the question of canalising or dockising the river Avon, and also to the general question of projecting solid piers from a sandy shore. He had hoped that the Papers would have supplied more materials for the discussion of those two subjects, but he had been disappointed, especially in the first Paper, that so little

allusion had been made to the subject of dockising the Avon. He had given this proposal a great deal of consideration nearly twenty years ago; and he believed he was the first engineer who opposed the idea of dockising the river. He entirely agreed with Mr. Abernethy, that if a dam were placed across the mouth of the river, which must necessarily be at some distance from the deep water, the space between the dam and the deep water would never be kept open, owing to the great quantity of mud held in suspension. He did not think that even the sluicing would be sufficient for maintaining a navigable channel. The only force that would be given by that means would be the river water of the Avon; and the state of the river above Bristol showed what sort of a channel that would maintain. It was true that some relief might be afforded by concentrating the twelve hours' flow into a few minutes; but even that, he imagined, would be insufficient to maintain a navigable channel. Another strong argument against placing a dam across the mouth of the Avon was that, with the river open as a tidal channel, small vessels could enter it from King-road within an hour or two of low water, and they would be up at Bristol before they could have entered into a lock at the mouth of the Avon; and the same thing would apply to larger vessels in proportion. There was, he believed, about 6 feet of water in the Swash channel. He had never seen any proposition for dockising the river which put the sill of the lock at a level lower than low water. Evidently the whole of the time the tide was rising from low water to 6 feet above the dock sill would be lost to the navigation of the river, and during that time vessels of all kinds might have been some way towards the entrance of the docks at Bristol. He was therefore quite in accord with Mr. Abernethy as to the desirability of maintaining the tidal flow of the river Avon intact. He thought the apparent advantages of damming the river were delusive, while for the smaller description of craft, in which a large portion of the trade of Bristol was carried on, the dam would be simply an obstruction. A vessel could enter a river much earlier than she could into the lock, and that he regarded as a very great advantage.

With regard to the other question raised by Mr. Abernethy, although he concurred to some extent in the principle laid down by that gentleman, he thought the principle was one which had many exceptions, and he did not think it ought to go to the world, especially from the Chair of the Institution, that the projection of piers from a sandy shore was in all cases a course to be deprecated. Mr. Abernethy had mentioned several instances of admitted

failure, and one or two anticipated failures; he had also referred to the case (which ought not to be regarded altogether as a failure) of the Suez Canal. Some years ago Mr. Parkes had held the opinion that it was useless to project such a pier as that at Port Saïd, because the sand would follow it up, and in course of time get round the end. He still held that such would ultimately be the effect; but he thought that the time it would take for the sand to get to the end of the pier would be so long that it might be left out of consideration. He had watched carefully the history of the Port Saïd breakwater. He visited the works some years ago, and had since examined the charts which had been published from time to time, and which showed that the progress of the shore seawards was so slow that the ultimate effect might well be disregarded. True the bottom was very treacherous, and liable to great and unaccountable changes; but, as far as he had been able to see, the projection of the pier had produced no deleterious effect upon the navigable channel. Such changes as had occurred were changes which had no connection with the works, and they were not of the kind which it might be inferred from Mr. Abernethy's remarks that he anticipated. He would like to have heard something rather more in detail as to the causes which had led at one time to the silting up of Whitehaven harbour. When harbours were projected, their silting up was always confidently predicted. Some harbours did silt up, but for one that did so, nine or ten did not. It was a matter of great moment to know what circumstances did cause such a result, and he should have been glad if some further explanation had been given of this particular case. As to the general principle, it was important to consider what was the cause of the movement of the sand on the shore: if that movement were caused by currents, no doubt there would be great uncertainty as to the results; but he believed that in most cases, certainly in many, the currents were of much less importance than the action of the wave striking the shore obliquely, and driving the sand before it. If the movement of the sand were due to the action of the waves, he thought that an extensive work was quite capable of overcoming that natural cause of deterioration. A small work undoubtedly would be rendered useless in the course of a few years; but so many years would elapse before a large work was affected by the advance of the shore, that he did not think the contingency need be taken into consideration. He had made some calculations in a work of that kind with which he was connected, and he found that it would take at least a hundred years before any serious effect could be produced. In that case there was no

trouble from currents; the only motive power acting upon the sand was the waves. People were frightened at it every year; but with the change of the monsoon (the work was in India) a great deal of sand was washed away again, and the work was left without any very formidable accumulation upon it. He thought it was rather premature to say that the harbour of Boulogne would prove a failure. That the ultimate effect would be for the shore to advance to the pier-heads, he did not doubt; but unless the currents were very strong indeed—so strong as to disturb the sand in considerable depths of water—he could see no reason why the harbour should not be a fair success. Mr. Abernethy had omitted to mention the very important harbour lately completed on the coast of Holland. The eminent members of the Institution who had carried out that great work would not, he expected, be inclined to admit that it was going to prove a failure, although solid piers had been run out from a shore composed of very light sand indeed.

Mr. GILES explained that he did not go to the extent of saying that a pier run out from a sandy shore was to be deprecated; he intended to say that it was probably only a question of time as to how long the pier would be useful—how long it would take for the sand to reach the end of it.

Mr. C. E. DANIEL said it was stated by Mr. Mackenzie that the average cost of the masonry was 20*s.* per cubic yard, exclusive of the facework, which was put at 2*s.* per cubic foot; and that this, added to the cost of the rubble masonry, would bring it to 25*s.* per cubic yard. He wished to ask whether that sum included all contingent expenses, wear and tear of plant and machinery, staff, and usual recognised contractor's profits? The same remarks would apply to the excavation which had been put by the Author at 1*s.* 6*d.* per cubic yard.

Mr. MACKENZIE said the sum was intended to cover the total expense of the works connected with those items.

Mr. GRAHAM SMITH wished to ask Mr. Mackenzie why the entrance to the dock was made in the peculiar shape described? He imagined that it must be due to some local circumstances. As far as his own experience went, it was certainly not adapted to the entrance of a dock, except for small craft, fishing-boats, and the like, which made straight for the entrance. Vessels of large tonnage made for the wall and were warped in by ropes and capstans, and the entrance was certainly not suited to that mode of manipulation. In Liverpool the entrances were fan-shaped. It was stated in the Paper that the sluices were provided with pen-stocks with cast-iron frames and brass faces. In Liverpool

there were hundreds of sluices, in which granite faces and wooden paddles were alone employed, and so far no difficulty had been found in working them. He was disposed to think that cast-iron frames with brass facings were an unnecessary mechanical refinement, somewhat liable to get out of order. Reference had been made to gates that were flat at the back, so as to enable ships to get into the dock without being caught in the recesses. That difficulty might be overcome by making the two uppermost ribs of the gates flat, and the remainder curved. In speaking of the apron, Mr. Mackenzie had stated that, after a certain amount of masonry had been put on the small springs, they were closed up. He thought it was a mistake to seal up springs. The quantity of water flowing from them was no gauge of their power. It was the head of water that had to be considered. If water from a spring got under the masonry, there were all the elements of a hydraulic ram, however small that spring might be, and for that reason it was a mistake to bottle up springs so that they might not show on the surface. With reference to concrete mixing, Mr. Mackenzie mentioned that he had employed the Messent machine, and that the work was better but slower than hand labour. He believed that the Messent machine was a slow one; but the Author's remark in reference to it seemed damaging to machine-mixed concrete generally. In Liverpool vast quantities of concrete had been made by machinery, and at the present moment five or six machines were in operation. They were of two descriptions. One was by Mr. Le Mesurier, of the Birkenhead docks, on the principle of Sir John Coode's machine, with a revolving cylinder inclined at a slight angle. The other, invented by Mr. Sutcliffe, engineer in charge of the construction of the new North docks at Liverpool, consisted of a moving band, on which the materials were deposited and carried up to a Jacob's ladder, by which they were turned over six or seven times; the band went underneath, and caught the mixed concrete after it came out of the ladder, and then the concrete was shot into the required position. He thought that any remark in reference to hand labour and machinery for mixing concrete ought to be qualified. If a large amount of concrete was required, and it was confined within a limited area, mixing by machinery was no doubt the best and the cheapest method; but where there was daylight and proper supervision, and the work scattered over a large area, he believed that hand labour would be the best. It appeared to him that engineers, when they built dock walls, were invariably in an anxious state until the water was got in, because the walls were always sliding about. The

same thing did not occur on railways. When a railway was built, the wall either toppled over altogether or stood firm. The reason was that railway walls as a rule had a good batter and the foundation at the same incline, whereas dock walls were almost always built with a base horizontal, or else at an inclination normal to the face of the wall, which was about 1 in 12. With an ashlar wall no doubt that ought to be done, but in dealing with concrete or rubble masonry there was no reason why the foundation should be normal to the face; and he was of opinion that if the foundations were inclined at 1 in 6, or at a larger angle, the walls would not slide about.

Mr. EACHUS said Mr. Giles had remarked that dock walls ought to be of sufficient weight to prevent their sliding forward, and also that it would be a great advantage to extend the toes considerably. That was rather extravagant advice. In his opinion all that was necessary in most cases was that there should be sufficient weight and sufficient width of base in the wall to keep it upright, and then the resistance to sliding forward ought, as far as possible, to be got from the maiden soil in front of the toe. He did not see any advantage in putting a long toe forward, as that involved opening out the ground to a greater extent than was necessary, without a corresponding benefit. If the resistance of the native soil were made the most of, it would be far better than adding unduly to the weight and size of the wall. The mode mentioned by Mr. Smith was one way of taking advantage of the resistance of the soil itself.

Mr. CLARKE HAWKSHAW was glad to hear Mr. Parkes say something in favour of piers on sandy coasts. It was obvious that there must be some limit to the silting or depositing of sand along a pier projected on a sandy coast. No doubt groynes were often constructed to accumulate shingle; but in most cases shingle accumulated along them for a portion only of their length, and many of them had been in existence for years, round the ends of which there was no accumulation whatever. He thought that it was not fair to cite the piers of Calais and Boulogne, or even Port Saïd, as examples. A certain amount of tidal water passed into the harbours through both Boulogne and Calais piers, and he believed that that had been also the case at Port Saïd at first. The blocks of concrete at Port Saïd were so large, and there were so many open spaces between them, that the tidal water passed through, and sand was deposited both inside and outside the piers. Moreover, the current was not increased round the ends, as it would have been in the case of solid piers. He had listened with great interest to Mr. Mackenzie's account of the difficulties encountered

in forming the foundations at Avonmouth; they were somewhat similar to difficulties that he had experienced at the Albert dock at Hull. Mr. Mackenzie had mentioned the Humber as even muddier than the Avon. There was one point with regard to the muddiness of those rivers worthy of note. Along the shores of the Humber, docks had been made, and more would be made, by reclaiming land from the foreshore. During the process of embanking the land for the Albert dock there had been an immense amount of deposit from the muddy waters of the river, increasing the earthwork to an extent which had not been anticipated. Engineers should be aware of that contingency, and provide for it. At the Albert dock there had been a deposit of not less than 12 feet over the whole area enclosed. In a dock 25 acres in extent that of course increased the earthwork very largely.

Mr. JOHN GRANT remarked that in the discussion on the Paper descriptive of the docks at Hull he had referred[1] to a point to which he would again allude—the importance of sinking sumps, cylinders, or wells, outside the proposed construction, several feet deeper than the lowest part of the intended work. He had adopted that principle in many cases, and was carrying it out in one or two at the present time. The sump or cylinder had to be sunk, and stone or gravel afterwards put in, to act as a filter and keep back fine sand or silt, before pumping was begun. One or more of these, according to the size of the work and nature of the soil, would make it possible to thoroughly dry the wettest ground, and get in the work solidly. With embankment or dock walls it was important to gradually carry up the walls and distribute the weight as uniformly as possible over the whole bed; also to take care as to how they were backed. The best designed wall would be likely to give way if backed up hurriedly with soft or semi-fluid material.

Mr. ABERNETHY desired to offer an explanation of some of his previous remarks, which he said had been misunderstood. He had suggested two important subjects for discussion in connection with the Papers. One was the difficulty of constructing deep-water harbours on sandy coasts influenced by littoral currents; and he had cited as instances of failure to construct ports of that class the ports of Boulogne, Calais, and to a certain extent Port Saïd. His remarks on that subject had to some extent been misunderstood or misapplied, at least by one member of the Institution. Mr. Parkes had expressed a desire that the remarks he had made from the Chair should not go forth as the generally accepted

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xli., p. 118.

conclusions of the profession. Those remarks were confined to the construction of harbours under the conditions specified. On sandy coasts, where littoral currents did not exist, the construction of harbours had been for a long time carried on with success. He had himself constructed harbours under those conditions. The conditions which applied to harbours in the English Channel, or in St. George's Channel (as at Whitehaven), subject to great littoral currents, did not apply to harbours on sandy coasts where such currents did not exist, or were not of sufficient force to convey the detritus held in suspension to and fro along the coast by the action of the tides. The accretive action which took place under the condition of the non-existence of those littoral currents was limited in extent, and, one might say, permanent in result. He could give numerous examples of harbours on the coast which fully bore out the proposition he had submitted. One of these was a harbour with which he had been connected nearly forty years—the harbour of Aberdeen—and he should like to cite it as an example to show that deep-water harbours, on sandy coasts not subject to powerful littoral currents, could be successfully constructed. Northward of the harbour of Aberdeen, for a distance of 28 or 30 miles, the coast was sandy, and was fully exposed to the north-easterly gales acting obliquely upon the shore; and that was the principal action to which harbours, constructed on sandy coasts where littoral currents did not exist, were subjected. Smeaton, before the projection of the north pier at Aberdeen, was doubtful of the results of a groyne at right angles to the foreshore, because the north-easterly seas occasionally led to the entrance to the harbour being choked up, namely, the mouth of the river Dee; and it was supposed that the pier would cause a great accretion, and an advancement of the foreshore similar to what had taken place under different circumstances at Boulogne and Calais. It was found, however, that that was not the case. There had been a very slight accretion on the landward end of the north side of the pier, and that had remained permanent to the present time, notwithstanding the further projection of the north pier under the advice of Sir John Hawkshaw and himself. Mr. Parkes had indirectly referred to a work on the coast of Holland, which had been completed under the direction of Sir John Hawkshaw. That work—the construction of piers forming the entrance to the Amsterdam canal—was situated on the shores of the North Sea, not on the shores of the English Channel; and the only accretive action to which it was subjected was that of the northerly and southerly on-shore gales, acting obliquely on the coast. As in the case of the Aberdeen harbour, a very limited accretive action might take

place, and that limited action would arise in this way. Supposing a gale to be blowing from north or south, although the deep-water waves might be in the direction of the wind and at right angles to the coast, when they approached the coast, by the arresting through friction of the base of the waves, the crests travelling onward, they became waves of translation, pivoted gradually round, and broke upon the coast in a parallel direction. There would probably be the kind of accretion as at Aberdeen, on the north and south sides of the piers projected by Sir John Hawkshaw—limited, permanent, and defined, and without affecting the entrance to the harbour. It would, no doubt, be subjected to accretion from the deposit of detritus held in suspension by the water, in the case of direct on-shore gales; but that could be removed by dredging, and he had no doubt that a deep-water harbour could be permanently maintained. It had been a very proper rule of the Institution, that an engineer should not express his opinion twice upon the same subject, and he should not have transgressed that rule, but for the fact that his only object had been to direct the attention of the Members to the discussion of two important points, instead of having all their time spent on minor matters of detail connected with the construction of dock walls; he therefore asked permission to add a few words to what he had already said with regard to the ports of Calais and Boulogne, particularly the latter work, and to explain more fully his reasons for the assertion he had made. As far back as March 1872, he had had an interview at Boulogne with the Maire, Mr. Adams, the projector of the work, and the engineers, who desired that he should coincide with them in opinion as to the possibility of constructing such a work. He had referred to the notes which he had taken, and the arguments he had used against the possibility of forming a deep-water harbour under the conditions to which he had referred. Those conditions were the strong littoral currents in the English Channel and the great accretion of sand at the harbour; and, the same cause remaining, a further projection of those works would merely continue and aggravate the failure of the existing harbours. A diagram had been exhibited (Fig. 3), showing the work projected for the improvement of the harbour of Boulogne, presenting two conditions of parallel piers. It was, he believed, proposed to prolong the north pier as an open pier for a considerable distance—nearly a mile—into the sea; to construct a solid pier of masonry to the southward, for a still greater length in the direction shown, leaving an opening of 820 feet. The argument he had used at Boulogne was that, by the projection

of this work, the littoral currents, running parallel with the coast as they did at present, would be deflected, and would pass seaward not parallel with the coast; that an eddy would constantly be created at the entrance of the harbour, and that the sand would be deposited there. He also argued that, although a littoral current existed, the advancement by accretion of the foreshore would gradually diminish the depth of the water constituting that littoral current, and so decrease its erosive action; and further, that the projection of the pier would tend to increase the shoal which lay immediately outside the entrance, known by the name of the "Bassure de Baas." Those were the arguments he had used in 1872, and he still adhered to them, his decided opinion being that the work now in course of construction at Boulogne for a deep-water harbour would end in inevitable failure.

Mr. HAYTER understood that the discussion was on dock works, not on harbours, otherwise he would now reply to Mr. Abernethy's remarks on the North Sea piers at the entrance to the Amsterdam canal. He did not agree with all that Mr. Abernethy had said; but as he proposed to offer to the Institution a Paper on the Amsterdam canal, which would include a description of the North Sea piers, that would be a more appropriate occasion to discuss the question as to the construction of close piers on sandy shores where there were strong littoral currents.

It must be evident to all that the difficulties which had to be surmounted at Avonmouth and Belfast were of no ordinary kind; and he thought that the Authors of these Papers had scarcely done justice to themselves, and had somewhat underrated the magnitude of these difficulties. At Avonmouth, for instance, quicksand had been met with in large quantities. In the construction of the Albert dock at Hull, with which he had been associated, quicksand had occasioned much trouble; but, as this work had been described to the Institution by his partner, Mr. J. Clarke Hawkshaw,[1] it was scarcely necessary to go over the various points again. It might suffice now to say that the great difficulty there arose from the circumstance that a system of borings had been made by others before the works were begun, which tapped the sand and caused it to rise, undermining the superincumbent material; and it was evident that if, under like conditions, borings have to be made, it would be well as a rule to keep them away from the site of the walls. Mr. Mackenzie had stated that, when the sand at Avonmouth was covered with only about 6 inches of clay, it

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xli., p. 92.

was kept under control; and that was the experience at Hull. At Belfast a material of a still more difficult character was met with, described as a "pulpy, semi-fluid mass." This work was a very instructive one, and he would presently again refer to it.

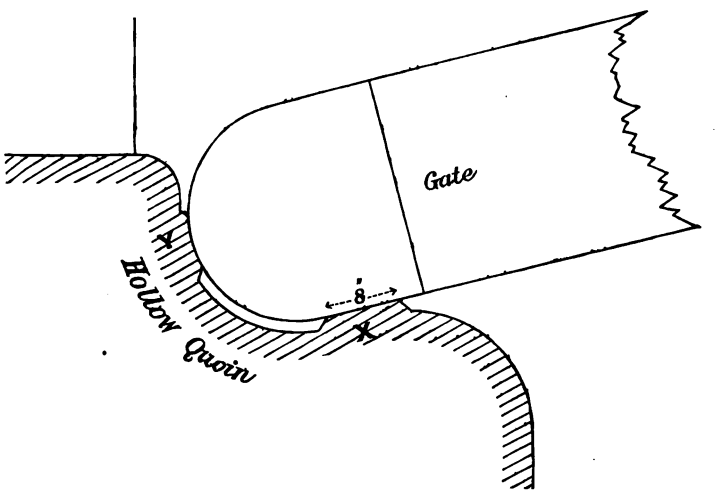
With regard to Avonmouth, Mr. Mackenzie had stated that in October 1859 the Town Council of Bristol had submitted several schemes, which he enumerated, to the late Mr. T. Page and to Sir John Hawkshaw. It would rather appear from that statement that a joint report had been presented by those gentlemen; but such was not the case. Each report was separate, and each of these engineers arrived at his own conclusion in his own way, without communication with the other; and they both discouraged the notion of dockising or canalising the river, recommending instead the construction of a steam dock at the mouth of the Avon, a railway connecting the dock with Bristol on the margin of the river, and the improvement of the river Avon. Mr. Page proposed a very extensive scheme, much larger than that suggested by Sir John Hawkshaw, whose proposed dock was that which had actually been carried out by Mr. Brunlees, and hence approved by him. The site was almost the same, and the direction of the lock, and the lines and size of the dock generally, similar. Mr. Mackenzie stated that the lock gates for Avonmouth dock were originally designed of wrought iron with cast-iron heel-posts, but that the high price of iron in the beginning of 1873, when the contract was settled, had led to the adoption of timber. That opened out an important question (which he was sorry had not been discussed) as to the comparative merits of iron and wooden gates. He had been engaged in the construction and erection of many pairs of gates, some of iron and some of wood—more, probably, of the former than the latter. Iron gates had to be constructed as caissons, and there was a great deal of difficulty in making them perfectly watertight, so much so that it was the custom to have a small pump at hand to pump out leakages. He believed that if wooden gates were made of greenheart timber, they would last quite as long as iron gates, and they would be less troublesome and less costly to maintain. He would not adopt iron heel-posts, because it was difficult to make a good joint between a long length of cast iron and a long length of masonry. According to his experience wooden gates were, on the whole, better than iron, and their adoption had been universal in Liverpool, where wooden gates were made of 100 feet span. Mr. Brunlees had probably arrived at the same conclusion, because in his later work at Whitehaven he had adopted wooden gates. Wooden gates were specially to be preferred

when near the sea, as the sea water and the exhalations therefrom rapidly deteriorated wrought iron. With reference to their comparative cost, the Author had stated that the cost per square foot of superficial area of the back of the gates was £1 6*s.* 1$\frac{3}{4}$*d.* at Avonmouth. That was for gates of greenheart, oak, pitch pine, and Memel, in combination. A wrought-iron gate was ordinarily estimated by him (Mr. Hayter) to cost between £1 10*s.* and £2 per square foot when iron was at about an average price, and he believed that, if gates were made entirely of greenheart, their cost would not exceed that sum. In reference to the rollers and the roller-paths, Mr. Mackenzie stated that the true position of the roller, the axle of which ought to be placed upon the line which passes through the centre of the heel-post and the centre of gravity of the gate, was difficult to determine with accuracy. That was true, and the conclusion at which he had arrived was that, unless under exceptional circumstances, it was better to abandon rollers altogether. Obstructions also often occurred on the roller-path, sometimes rendering it necessary to send down a diver to clear them away; and if the lock or entrance passage had only one pair of gates the dock might get emptied, and much damage be thereby occasioned to the shipping. Taking into account the roller, the spindle, the adjusting apparatus, the roller-path, and the elaborate masonry necessary to receive it, an extra cost was involved of between £400 and £500 for a pair of gates, assuming the lock to be 50 or 60 feet wide. In Holland rollers were never introduced in the gates. It was true that the differential head was only small there, but the omission of the rollers was an advantage. If the gates were of an exceptional span, say 100 feet, perhaps one roller in each leaf might be introtroduced: but this was an open question. Under no circumstances should there be two rollers to a leaf. It was only necessary to make the anchor and pivot sufficiently strong—and they were always made with an excess of strength—and rollers could, as a rule, be abandoned with advantage. He wished to add a word with reference to the best way of making a watertight joint between the gate and the hollow quoin. This was usually done by the accurate fitting and close contact of the circular surfaces, which was not easy to ensure, and there was generally more or less leakage around the hollow quoin. There was often also in opening the gates a great deal of friction between the surfaces, to overcome which some engineers placed the pivot a little out of the centre; but the objection to this was that immediately the gate was moved there was a space between it and the hollow quoin, into which loose material might lodge, rendering it impossible to

close the gate, or bringing a great strain on it. The Dutch had a good way of making the watertight joint, shown on the accompanying sketch.

It would be seen that the hollow quoin was brought more into the lock than usual, and the joint made against a straight face at X, usually about 8 inches wide, and which was polished from top to bottom, and a clearance given at the hollow quoin, excepting at the upper portion Y, where the gate was brought close to prevent loose material being carried around the hollow quoin. This arrangement —perhaps a little more costly owing to the encroachments on the

FIG. 1.




lock—was nevertheless satisfactory, and appeared to be an improvement upon the usual plan adopted in this country. It was evidently easier to make a watertight joint between straight surfaces than between those that were curved.

The failure of the wall at Belfast had been due to three causes: first, the insufficiency of the depth of the walls; secondly, the very light pile work in the foundations; and, thirdly, the bad material constituting the backing. In 1871 Sir John Hawkshaw was called upon to report upon the walls when they were in an exceedingly critical state, and he recommended four modes of dealing with them. The first was the construction at the back of the wall of screw-pile work surmounted by a platform; that was generally the plan alluded to by Mr. Giles, and adopted by him at Southampton with success. The second plan, which was recommended as an alternative proposal, was screw-pile work and masonry at the back of the wall, generally similar to that shown in Plate 1,

Fig. 11, in Mr. Mackenzie's Paper. It would have been a costly mode, but effectual, as it would almost completely relieve the pressure at the back of the wall. It would have been necessary to resort to screw piles, because, if piles had been driven, it would have shaken the wall, which could bear no extra strain. The third plan was an improved system of tying back the walls. The ties were to have been 3 inches in diameter, and fastened at the back to a continuous wall of brickwork 4 feet 6 inches thick and 12 feet high. The objection to that was that, the tendency of the wall being to go out at the toe, the ties should be as near that point as practicable. They were, however, more than halfway up the walls, and the reason why they were so placed was that it was almost impossible to get down to fix them at a lower level. The fourth plan was a system of counterforts at the front toe of the wall, which were to consist of concrete blocks placed about 6 feet from the wall, the intermediate space being filled with liquid concrete, and beyond the blocks there was to be a platform of broken whinstone and sand. Altogether the counterforts would have been about 30 feet long and 6 feet deep, the level of their upper surface being that of the dock bottom. This plan was considered preferable, and if it were found to be difficult to execute, it was recommended to continue the system of tying back, and if that did not answer, then to resort to one of the first two plans described. The counterforts were estimated to cost about £5 per lineal foot of wall, and the tie-rods £7 per lineal foot, if placed 10 feet apart. He did not know whether Mr. Salmond had carried out the counterforts as described, and if not, it would be interesting to know the reason why. Perhaps (and in that he sympathised with him) he might have felt unwilling to disturb the toe of the wall, fearing it might to some extent endanger the structure. The counterforts would, of course, have had to be put in in very short lengths, and divers must have been employed, as it was impracticable to empty the water in the dock. He considered the Whitehaven dock had been almost entirely out of the discussion, solely because there had been no failures there. The works had been successfully carried out without mishap, and were very creditable to those engaged in their construction. He had seen the Whitehaven dock, which presented features of interest.

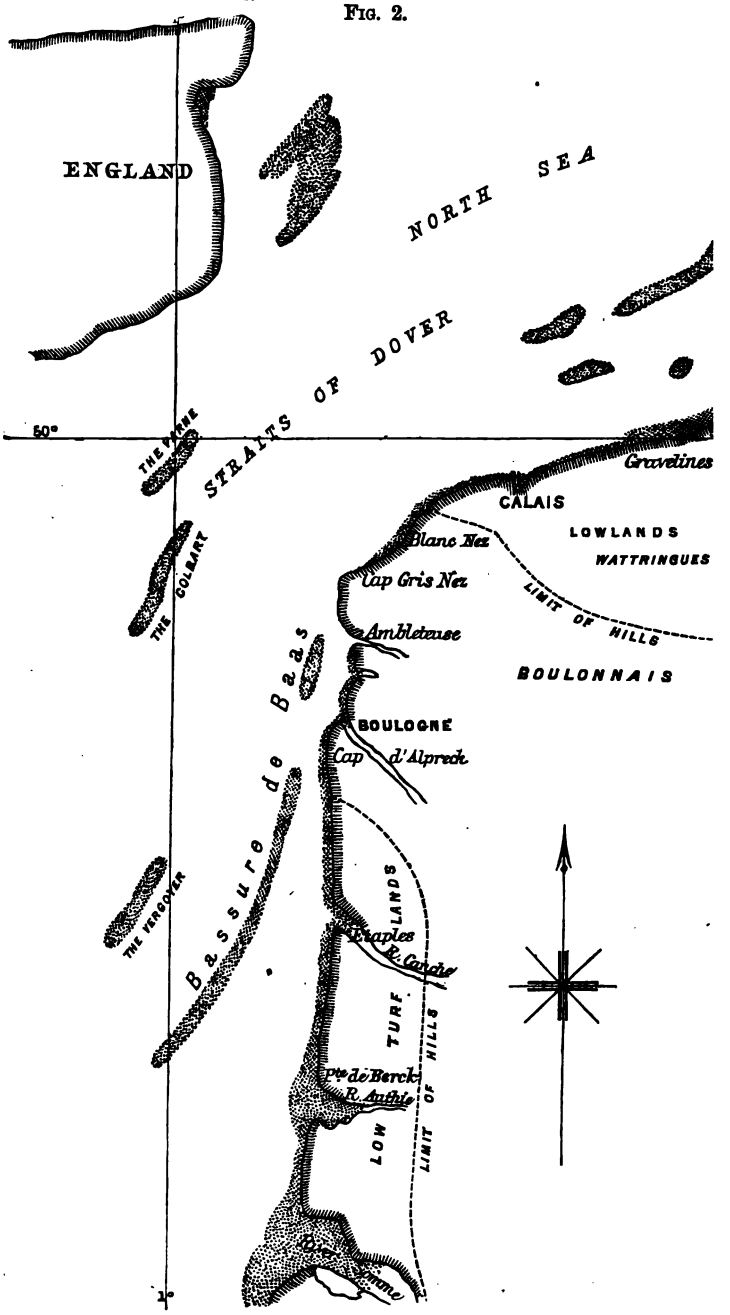
M. C. Bergeron had heard Mr. Abernethy criticise the projected harbour of Boulogne, and explain that probably that harbour would be choked by a sandbar. As he knew M. Stoecklin, the Engineer-in-Chief at Boulogne, who thought there was no possibility of such an occurrence, he had requested that engineer to attend and defend the scheme. This he was unable to do by the pressure of other

occupations, but he had sent some written observations, which M. Bergeron hoped might be permitted, under the circumstances, to be read.

These were, in fact, extracts from a report by MM. Stoecklin and Laroche, which would shortly be published. They observed that for many years the improvement of the port of Boulogne had occupied attention, and various projects had been submitted in connection with it. Plans had been successively proposed for the prolongation of the existing jetties; for great breakwaters detached from the shore; for harbours, more or less enclosed, formed by jetties thrown out from the land; and for harbours in the open sea, connected with the shore by stockades of wood or of iron. The majority of these projects had remained in the region of vague propositions, and had not led to any practical elucidation of the question. The only plan which appeared to have been submitted to a detailed examination was that for an open roadstead, submitted in 1854 by the Chief Engineer Béguin. The matter was only seriously undertaken in 1872, when the representatives of the town of Boulogne sought powers for the construction of an outer harbour. But the plans sent in were not of a nature to dissipate the apparently well-grounded fears of silting up. It had become almost an axiom that the bays on a coast subject to shifting sands would shoal, and that groynes thrown out from the shore induced deposits, which soon distorted the shore line. Moreover, the port of Boulogne was situated, not only on the large bay between Cape Alpreck and Cape Gris Nez, but, further, at the bottom of the secondary inlet between the Pointe de l'Heurt and the Pointe de la Crêche. It was also well known that there existed in front of Boulogne a considerable movement of detritus, resulting from the erosion of the cliffs of Normandy. However, a close investigation of the coast at this point had led to the belief that, notwithstanding these apparently unfavourable conditions, the situation of Boulogne was appropriate to the construction of a deep-water harbour. He proposed to summarise the results of the survey in question, and the considerations on which the project recently approved had been based. An indispensable preliminary in all such plans was the precise determination of the economy of the coast, which was the resultant of the geological constitution of the soil, and of divers forces brought to bear upon it. If the shores of the English Channel were considered from the geological point of view, it would be found that, going northward, after the cliffs of Normandy, which ended at Bourg d'Ault, there existed, first, a somewhat deep gulf between Bourg d'Ault and Cape Alpreck; and then the large promontory of the Boulonnais, from Cape Alpreck to

ENTRANCE OF THE THAMES.

FIG. 2.




THE STRAITS OF DOVER.

Capes Gris Nez and Blanc Nez. Hence, along the shores of the North Sea, were found the low-lying lands of Flanders and Holland, known as Wattringues and Polders. Possibly at a past geological epoch the Straits were for a time closed: that was a matter for discussion; but it was very certain that the communication between the Channel and the North Sea was only maintained by a narrow canal, and that, as a consequence of the different conditions which obtained in the two seas, the shores of the Straits must needs be, and were, subject to violent erosion. Again, the coasts of France and England were bounded, at the Straits of Dover, by steep cliffs; and M. Larousse, in soundings made across the Straits in 1875 and 1876, found the bottom, at depths of from 120 to 210 feet, to consist of the natural soil, entirely free from sedimentary deposits. The general law formulated by the saying, "Capes are eaten away, bays filled up" (*Les pointes se rongent, les anses se comblent*), had a perfect illustration here. The gulf comprised between Bourg d'Ault and Cape Alpreck had disappeared, and its only traces were an absolutely flat plain, a few peat bogs, and the estuaries of the Somme, of the Authie, and of the Canche. All along the coast was a series of dunes and nearly straight beaches of sand. On the other hand, the promontory of the Boulonnais had been continuously eroded, but, as it was formed of beds of different consistency, the wasting had been irregular. The rock resisted more or less, according to its hardness, and formed headlands, while the clay beds and gravel were disintegrated more easily. This it was which gave to the coast between Cape Alpreck and Cape Gris Nez the toothed appearance, resulting from a series of points with intermediate gaps. In the immediate neighbourhood of Boulogne were the Pointe de l'Heurt and the Pointe de la Crêche, both formed of the hardest rock (*grès à ammonites gigas*), and between them an inlet resulting from softer strata. But, if this inlet could be called a bay, could the foregoing general law be applied to it? Scarcely. The law applied only to capes and bays already existing, and not to those in course of formation; and to prove this it was only necessary to instance Dungeness, which advanced every year into the sea at the rate of 4¼ feet; and the Bay of Saint-Jean-de-Luz, which continued to enlarge in spite of all the obstacles presented to its extension.

The bay of Boulogne was also a bay in course of formation, of which the axis was a function of the distance of the limiting points, of the nature of the soil, and of the action of the sea. To make the conception understood, it might be said, that, if, for example, a width of 1,300 feet were cut off from each of the Pointe

de l'Heurt and Pointe de la Crêche, the bay would extend inland a corresponding distance of 1,300 feet; furthermore, that, if the soil were mud or fine sand, more easily eroded than the existing soil, then the bay would describe a much more pronounced curve inland.

With respect to tidal economy, two circumstances specially affected the neighbourhood of Boulogne: the great rise of tide, and the existence of an alternating current that did not synchronise with the tidal oscillation. As an instance of this, the equinoctial spring tide of the 1st of March, 1877, attained a height of 30 feet, while the same tide only made 22 feet 2 inches at Cherbourg, 23 feet 6 inches at Calais, and 20 feet at Dunkirk. On the other hand, the alternate current flowing past Boulogne did not agree with the tidal movement; for the flow (from south to north) only began three hours after the time of ebb, and continued three hours after high water; its maximum speed, which exceeded 3 knots an hour, or say 5 feet a second, nearly corresponded with flood tide. In the ebbing current (north to south) the greatest speed was 2 or 2½ knots an hour, corresponding with ebb tide. From this it followed that a vessel anchored off Boulogne swung at half-flood and at half-ebb. Furthermore, MM. Gaussin and Estignard and M. Ploix had noticed at Boulogne that this current acted through the whole depth of water; and the observations of M. Larousse proved that the same obtained throughout the whole width of the Straits.

To the action of these currents was added that of the tides and that of the waves. These two latter forces preponderated in the case of the beach, and from near low-water mark to depths of 13 to 16½ feet below, but from there the influence of the waves became less intense, and that of the current predominated. The current eroded the bed of the channel between the Bassure de Baas and the shore, while the waves tended to flatten and level the beach. In its general features the coast to the right of Boulogne appeared like the concave bank of a great river, a bank which had been fixed by means of two great groynes, the Pointe de l'Heurt and the Pointe de la Crêche. In fact, these headlands constituted supporting ribs; the natural soil was exposed everywhere on the bed of the sea; the slope of the shore was broken in many places, especially at depths of 23 to 26 feet, above which the slope of the superior bed fell to 1 or 2 per 1,000, while the inferior bed had an inclination ten or fifteen times as great, occasionally reaching 7 or 8 per 100. After the groynes came a cavity, and as the current flowed alternately each way, the cavity existed on each side of the groyne, and resulted in a corresponding enlargement in the middle.

The contour lines closed round the capes, especially round the Pointe de l'Heurt; the tide, swollen in the ascent, divided—one stream flowed between the Bassure de Baas and the land, the other spread out and produced the depression observed here by M. Ploix. Between these two currents there was a relative calm, which explained the formation and the maintenance of the bank. Not only did the sand stop there more easily, but the soil itself was less vigorously attacked.

The up-current being stronger than the down-current, there occurred what had been called a tidal gain (*gain de flot*), that was to say, the sand travelled from south to north; and as, on starting from the contraction caused by the projection of Gris Nez, the coast fell back, and the section increased in a large proportion, the alluvial soil was deposited, and formed and fed that series of banks cut up by channels which were found before Dunkirk. On the beach the currents were also felt, but their action was modified by the preponderating influence of the waves. The waves eroded the beds of clay and gravel, and afterwards filled up level with sand the holes produced between the banks of rock. But in spite of the presence of this sand, the shore at Boulogne was far from being what was ordinarily called a sandy shore—between the Pointe de l'Heurt and Pointe de la Crêche, where there were at every step masses of rock or gravel; and the borings executed by M. Legros in 1872 justified the idea that the layer of sand had nowhere a greater thickness than 9½ feet. If this layer were removed, the cliff would be found everywhere of the same character under water as above, and producing, in consequence of the very different beds of which it was formed, the tidal gain mentioned by M. Ploix, and the irregularities met with in the bottom, and which it would be absolutely impossible to explain in the case of a shore of sand.

The theory above enunciated had been supported by observation. A hydrographic survey of the shore in the neighbourhood of Boulogne had been made with great care in 1876, under the direction of M. E. Ploix, Hydrographer of the French Navy. Comparing the results of this examination with those made in the same neighbourhood in 1835 by Beautemps-Beaupré, and in 1855 by MM. Gaussin and Estignard, M. Ploix had arrived at these conclusions: that there had been no appreciable modifications of the shore in general from 1835 to 1855, and from 1855 to 1876; that the cliff continued to recede; that the great depths had remained the same, and that the contour lines starting from 16 feet had not sensibly varied. The deposit of sand, caused by the jetties of Boulogne, constructed in 1835, and by the Portel jetty in 1867, had produced very little effect on the

bottom above 16 feet depth. The existence of these deposits did not conflict with the theory enunciated, and they were not of a nature to compromise the future of the new port.

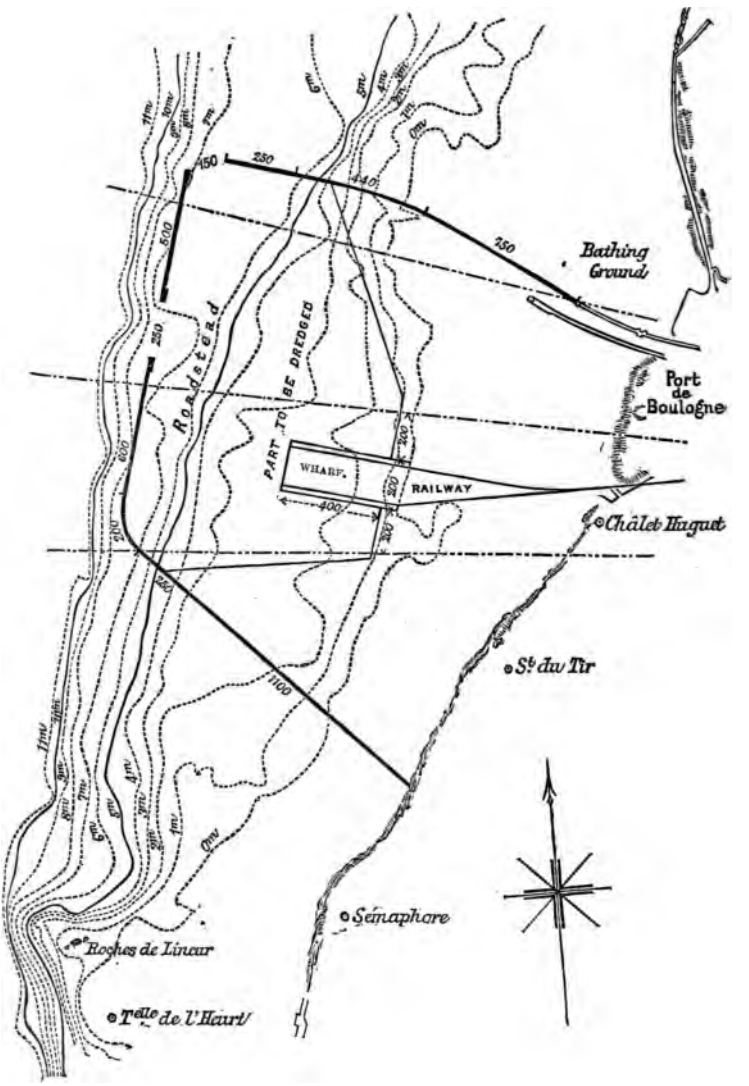
These observations determined the character of the new works, and the system on which they should be constructed. Any work the extreme point of which should not attain the limit of the influence of the Pointe de l'Heurt and Pointe de la Crêche would have no sensible effect on the great depths, and would produce on the upper strand an elevation of little importance. Any work that should project into too deep water, starting from the contour line of 16 feet, would act as a groyne and produce similar effects. Now a groyne (of which the effect was not suppressed or hindered by neighbouring groynes) caused, on the one part, eddies or counter-currents, which eroded the shores to a certain distance on both sides of the groyne, and, on the other hand, specially tended to produce banks on the down-stream side. Here the same cause would produce the same effects, only these effects would be, to a certain extent, modified by the alternation of the currents, and by the superposed action of the waves. The counter-currents would continue to exist along the shores at a certain distance; but the banks, continually worn away by the waves, would probably never attain any great height. Furthermore, the sand would accumulate in the angle between the construction and the coast, especially on the side of the prevailing winds, that was, on the south-west side. A simple jetty, therefore, whatever its length and its direction, would have the fatal consequence of encouraging silting up on both sides; and therefore, in the proposed roadstead, and in front of the existing port. There was no escape from the danger save by creating an enclosed harbour, of which the whole would form a groyne and deflect the deposit to a spot beyond the space enclosed. Two other plans would, it was true, accord with the theory enunciated, and had, in fact, been considered. One was a system of isolated break-waters; the other, the construction of jetties prolonged to great depths. This last system was proposed about the year 1840 by Chief Engineer Marguet. It was conceded that such a plan might result in the establishment of a deep-water entrance; but it would be impossible with single sluices, and difficult with dredging machines, to maintain this depth for the whole length of the channel. And if ever it could be done, it would be necessary, in order that all the advantage might be obtained, to reconstruct nearly all the existing works of the port. The question was, therefore, Was it not preferable, instead of reconstructing the works under the most difficult and onerous conditions, to utilise what

already existed, and to employ the new funds in the formation of additional outer works? True, the apologists of the plan in question, appeared to confine their ambition to obtaining from 3 to 4½ feet depth of water on the bar at low water of spring tides. This would certainly be an improvement on the present state of things, since now the bar was 3 feet above low water. Nevertheless, taking into account the special nature of the traffic at Boulogne, it might be asked, if this advantage would sufficiently counterbalance the inconveniences resulting from the prolongation of the jetties, viz., the liability of vessels passing to windward, and of avoiding the others, in a channel a mile or more in length; the danger of such a narrow channel jutting out to great depths with strong currents; the propagation of the concentrated swell before it had been deadened by the shore; the great expense? And if the jetty plan did not present such overwhelming advantages over the maintenance of the *status quo*, still less could it enter into competition with an enclosed harbour, by which not only would the existing inconveniences be remedied, but an anchorage and new harbour appliances would be supplied. With regard to the plan of an open roadstead, procured by the construction of a single isolated breakwater, as proposed by M. Béguin in 1854, and by MM. Gaussin and Estignard, and referred to by M. Ploix, this also presented serious objections. Indeed, if a breakwater were constructed on the Bassure de Baas, it would be necessary to extend it considerably to be efficacious. (In 1856, the Committee of Naval Construction and of the Admiralty declared that it would be necessary to make such a breakwater 7½ miles long, which would have cost, at the prices then ruling, £7,100,000.) If placed nearer the shore, it would be still very inconvenient, in addition to the cost that such a work always entailed. What made Boulogne an exceptional case, was the existence of this current—this river between the Bassure de Baas and the shore. In his opinion, therefore, it was advisable to interfere as little as possible with the current, by not encumbering its bed. In any case, he shared the fears already expressed by the General Council of the Ponts et Chaussées on the 1st of April, 1856, of seeing the channel between the breakwater and the shore gradually silted up, as this channel was in part cut off from the action of the waves, and even of the currents, by the construction of the breakwater. Besides this, the smoothness of the water behind the breakwater was uncertain, and might well not be sufficient for the establishment of wharves and landing places.

The careful study of the character of the coast led, therefore, to the conviction, that the plan of a deep-water port was realisable,

and that its best form would be an enclosed port on the south of Boulogne, encompassing the entrance of the existing port. It was

FIG. 3.




THE PROPOSED NEW HARBOUR AT BOULOGNE.
N.B. All the depths are in mètres under low water of spring tides. The part to be dredged is to be removed to a depth of 5 mètres.

on this system that the project recently approved by the General Council of the Ponts et Chaussées was based.

Two principal objections had been made to the scheme: one, the silting up of the entrances by sand; the other, the silting up of the interior. If the condition of the coast was really what he had sought to describe, it might be unhesitatingly admitted that the entrances would not become shoal. It was doubtful whether, if the Pointe de l'Heurt were united to the Pointe de la Crêche by an embankment, either straight or slightly concave, it would not be undermined, rather than silted up by the current. The same effect would be produced by a part of this embankment. The harbour works, as a whole, if not placed behind the curve formed between these two points, would constitute a groyne, and there would be a denudation at the head of this groyne, such as had been produced at the Pointe de l'Heurt. Deposits would doubtless occur to the south and to the north, but such deposits, which furthermore would not endanger the port, would probably not attain any great height, because the direct effect of the groyne would be opposed by the action of the waves. But it might be assumed, with M. Ploix, and with the Nautical Commission, that the channel would remain free from any deposition of sand. As regarded the deposition of silt, the clean state of the neighbouring beaches, which were of pure sand, and the absence of all mud banks under the shelter of the points de l'Heurt and de la Crêche, justified the belief that any such silting inside the roadstead would be unimportant. As a maximum, half the amount of 3 inches per annum given by Captain Washington, in 1845, as the rate of accretion at Dover, might be assumed. The deposit at Boulogne would not exceed 300 cubic mètres per hectare (850 cubic yards per acre) per annum. The new port of Boulogne was, therefore, of good promise, and had great chances of success. For the construction of the jetties at Boulogne the compound system would be adopted; that was, jetties on a mixed foundation of natural rock, random work, and surmounted by walling from the level of low water of spring tides. The weak part of a mound wholly of random work, as at Plymouth, was that above low water. Such mounds were subject to continual damage, and needed an enormous quantity of material for their maintenance. Jetties formed throughout of solid walls, as at Dover and Tynemouth, were very difficult of execution, and cost much time and money; their weak part was below the level of low water. It was, therefore, reasonable to cull from each system only its advantageous points; and this had led to the employment of random work below low water, and walling above.

Mr. Russel Aitken had considered harbours in connection with

the question of the travelling of sand and shingle along the shore. He thought that both Mr. Abernethy and the designer of the harbour at Boulogne were correct, and that the question was only one of degree. When the Tyne piers near Newcastle were first started, the sand accumulated against the south pier, and then passed round it on to the bar as usual. After the south pier had been carried out a considerable distance, the sand still continued to accumulate, but, as it had a longer expanse of beach to rest on, it did not proceed so fast. The south pier was now very far ahead of the sand; in fact there was ample room for the accumulation of sand for, he should say, at least one hundred and fifty years. The same kind of action had taken place at Dover. Formerly shingle used to go along the south coast and pass over the entrance to Dover harbour. Mr. Ralph Walker had put up a sluicing apparatus, by which he endeavoured to force the shingle accumulating in front of the entrance away to the north. That was only partially successful, but it had some good effect. Since the cliff to the east of Folkestone had been blown down for the South-Eastern railway, the shingle that travelled along the shore had been retained there, and none of it passed the harbour. The Admiralty pier was free from shingle, and not only so, but, owing to the want of the usual shingle coming along the coast, the South-Eastern railway to the West of the Admiralty pier was being undermined by the action of the waves on the unprotected chalk cliffs. It was a mere question of quantity; so far as he could judge he did not think that the accumulating sand would be any obstacle to the construction of a harbour such as that proposed at Boulogne. The same difficulty was urged when he was in India against the construction of the Kurrachee harbour, and it was said, "All you will do will be to put the sandbar farther out." He had been asked to report upon the subject, and he had pointed out that the sand which travelled along the shore was due to the waste of the coast, and that if it was stopped by a pier there would certainly not be a sufficient quantity of sand accumulating to require the extension of the pier for a long time. After the pier was made the sand was stopped, and the bar was dredged away. He had attended the opening of the Suez Canal, and had seen the sand accumulated there. No doubt a considerable quantity came from the Nile along the coast, but on recently looking at the chart it did not seem to him very serious. All that was required was to take the concrete blocks, which were covered up by the sand at the harbour end of the west breakwater, and prolong the breakwater farther out. With regard to the harbour at Boulogne,

no doubt after a time, when the larger particles of sand had filled up the angle formed by the west jetty and the shore, they would go in front of the entrance and block it up, so that there would be but little more than 8 feet of water over the entrance; but the question was, whether in designing works of that kind, engineers were bound to provide for more than a certain number of years. Neither towns nor nations existed for geological periods, and works that provided for a certain reasonable term of years might be accepted as satisfactory.

Dock walls always appeared to him subjected to a sort of rule of thumb, both in their section, and in the mode in which they were put up. He thought it quite possible that the very best wall would fail or break, and get out of shape, unless it were properly supported at the place where the greatest pressure came on it, when the backing had been put in. In constructing retaining walls for holding up water in reservoirs, the resultant of the combined thrusts of the water and the weight of the wall should on no account fall outside the centre third of the base of the wall. In that case, if the weight of the masonry dam pressed on the foundations, say with a pressure of 6 tons per square foot with the reservoir empty, when the reservoir was filled, and the water pressing against the dam, the pressure at the outside of the base of the dam would be doubled, and would reach 12 tons per square foot, whilst there would be no pressure on the base at the inside edge of the masonry. But in dock retaining walls the resultant of the thrust of the weight of the backing and the wall itself was taken much nearer the outside edges than the centre third of the base of the wall; thus the pressure at the outside edge of the wall was very great per square foot of the area of the ground on which the base of the wall rested, and there was no pressure on the base at the inside edge. Hence if the ground on which the wall rested was soft, compression took place under the outer edge of the base of the wall, and the top part of the wall moved forward. The logical conclusion was, that there ought to be a large toe in front of the wall, and at the same time that it should be so made that the pressure due to the combined weight of the wall and the resulting pressure should not exceed a certain maximum, which should be regulated by the nature of the foundation.

Sir JOHN COODE said that in the remarks made by previous speakers justice had scarcely been done to Mr. Mackenzie's Paper. He had no wish to draw a comparison between the several Papers under discussion, but he thought that, whether in regard to the

narrative of works executed, of difficulties encountered, of failures suffered, or of cost incurred, it was an admirable example of what a Paper read before the Institution ought to be. He wished to give a word of friendly caution to engineers who might have to design docks for ocean-going steamers; and perhaps he could not do better than relate what had occurred to himself. Eighteen or twenty years ago he was called upon to design a harbour and dock works for an important port in one of the English colonies. The design contained a dock of the width of about 450 feet and a length of about 1,000 feet. He was met by the objection that the dock was too large. It was said, "This is far beyond our requirements; the largest mail steamer we have trading here is 650 tons;" the length of a steamer of that class would be about 200 feet. Fortunately the Governor was firm, and the design was carried out. Two years ago he visited the colony for the first time, and the steamer in which he entered the dock was 350 feet long, and about 3,000 tons burden; and there was a general idea prevailing that, if anything, the dock wanted enlargement. It was fortunate that the design had been adhered to, because the dock had been used by the largest steamers trading to the colony, and no difficulty had arisen. But a time had now arrived when ocean steamers were rapidly increasing in length, and it was necessary that every dock to accommodate such steamers should admit of the largest vessel being able to turn round in the dock. And not only should the length of the vessel and the width of the dock be considered, but it should be remembered that a dock in full use would have steamers lying at the quays on either side, occupying, say, 80 feet of the width, and allowing 15 feet for clearance on each side, 110 feet. Mr. Giles has referred to a steamer lately launched for the Cunard line 450 feet long. In July last Sir John Coode had crossed the Atlantic in a steamer 490 feet in length. It was true she was the largest passenger steamer afloat; but steamers were now growing rapidly, and for the very dock which he designed eighteen years ago he was now called upon to consider the question of accommodating a steamer (probably more than one), now being built, 460 feet in length. He was satisfied that an engineer who had to design a dock in the present day for ocean-going steamers ought not to make it less than 600 feet wide.

Reference had been made to a concrete machine with which his name was connected. It was a modification of a machine invented by Mr. Ridley, and the peculiarity of it was that the machine was always in motion. It had a saucer-shape cover, which could be

advanced and pulled back, while the machine was revolving; the issue of concrete from the machine could be stopped, and the concrete could be mixed for two, three, four, or five, or more minutes, as might be desired, without allowing it to pass through. He had seen concrete machines in which the material had been thrown in at one end and went out with a bound at the other, an evil that led him to the adoption of the cover.

It had been said by Mr. Browne that the tidal flow up and down a river was an absolutely unmitigated evil. He should have taken that as a mere passing remark, but that the speaker had introduced it in a way that showed it to be his deliberate opinion. Mr. Browne said he supposed that Mr. Abernethy must have forgotten two things—that the Avon must escape somewhere, and that there was an average available head of 35 feet for sluicing purposes. Mr. Abernethy was quite aware that the Avon must go somewhere; but if it was thought that any great gain was to be obtained by using such a head as 35 feet for scouring purposes, he should like to call attention to what had happened at Birkenhead, with a head of only 20 feet. The most perfect sluicing arrangements had been provided, and they were used with great care and caution. Mr. Lyster reported fully to the Dock Board on the subject, and said that although the velocity of the issuing current was 15 miles an hour when passing through the sluice chambers, no portion of the material scoured away reached the river Mersey, which was 400 or 500 yards in advance of the sluices, and that actually some of the material had been deposited on the side at a distance of 300 feet from the sluice chambers. If the flow of the tidal water in the Avon was an unmitigated evil, certainly the port of Bristol, without the tidal water, could have had no existence. It would be a sorry day for Bristol if she depended on the fresh water of the Avon, just as it would for Newcastle if she relied solely upon the fresh water of the Tyne; and, coming nearer home, he did not know what would become of the port of London if it were solely dependent upon the fresh water of the Thames. At the present moment the water companies had power to consume from one-fourth to one-third of the summer supply over Teddington weir, and they were consuming very nearly that quantity. In the twenty-three years from 1849 to 1872 the quantity abstracted by the water companies had been trebled; and if it went on at that rate the time was not very remote when there would be no fresh water coming over the weir during the summer.

If the view expressed by Mr. Abernethy in his sweeping con-

demnation of ports on sandy shores were to hold good, in many cases harbours could hardly be provided at all. He had stated that at Whitehaven the combined effects of the west and north piers had caused a deposit on each side even to the extremity. The plan exhibited did not show it to be so. The accumulation at Whitehaven was not, in his opinion, due to littoral currents. He joined issue with those who maintained that the great accumulations at the side of piers and groynes were due to littoral currents. They were, he believed, mainly due to wave-action. That they might be and were modified by littoral currents there could be no doubt; but he maintained that the chief agency was the wave-action along the coast. In proof of that, he would only refer to the fact that very much greater changes would take place during one gale of twenty-four hours than during the six summer months when the littoral currents were in full action. With regard to Port Said, he might mention that it had been reported upon in 1870 by Admiral Richards, Hydrographer to the Admiralty, and Sir Andrew Clarke, Assoc. Inst. C.E., late Director of Public Works to the Admiralty, and the result of their inquiry was, that in the ten years, from 1860 to 1870, an area of about 45 acres of land had grown up at the back of the west pier; and they went on to say, that before the material could reach the end of the pier an area of about 1,400 acres would have to be filled up, which would represent a period of about three hundred years, supposing the action to go on at the same ratio, which he very much doubted. He certainly agreed with the broad principle, referred to by Mr. Abernethy, as to the importance of the conservation of tidal water; but he thought that the principle was often strained rather too far. There was another, not less important, principle, which ought to be kept in view, and that was the controlling, directing, and guiding of the power of the tidal currents, by perhaps narrowing at one point, widening at another, cutting off a broad point here, removing a shoal or obstruction there. By such means more good might be gained than by straining after the retention of a few hundredweights of tidal water in an estuary, which might perhaps contain millions of tons. It had been stated, that since the Round Down Cliff had been blown down, the shore to the eastward had been robbed of its shingle. A few years ago Sir John Coode was officially called upon by one of the Government departments to report on the question of the loss of shingle along the coast to the south of Deal, and the conclusion at which he arrived, and which had been confirmed by a recent examination was, not that the Down Cliff had retained the shingle, but that it had been

retained by the action of the South-Eastern Railway Company in the projection of the groynes at the Folkestone station. The company had constructed several groynes there, and by so doing had reclaimed some acres of land; thus had entirely, for the present, stopped the travelling of the shingle to the eastward of Folkestone harbour.

Colonel MARTINDALE said he should be sorry for it to go forth without qualification, that no dock for ocean-going steamers should be less than 600 feet wide. The Victoria Dock Company were now adding to the Victoria dock, already 1 mile in length, another 2 miles long. They had taken the best advice they could obtain, and were making the dock 490 feet wide, which he believed was 30 feet wider than the Clyde where it was frequented by the steamers of the Anchor Line. No difficulty was found in working a narrower dock. The Millwall dock, one of the most modern on the Thames, was 350 feet wide. There were large steamers at the quays on both sides. As a matter of fact, with proper appliances a steamer could turn pretty nearly on its centre. In the case of docks for a government, or for a corporation, to whom money was no great object, a width of 600 feet was all very well; but for a mercantile company, that wanted money for its shareholders, a dock might be safely worked if it was over 450 feet in width. For steamers exceeding that length there could be no objection to their being taken out stern foremost, which, on the Thames, was found to be a very convenient arrangement. If the width of a dock exceeded 500 feet it would be most convenient and economical to have it 1,000 feet wide, with jetties projecting on either side; but in the case of a dock of great length when the land on either side was likely to be of considerable value for building purposes, any dock over 450 feet wide would suffice for the largest ocean-going steamers.

Sir JOHN COODE did not mean that a dock should be 600 feet wide for the whole of its length, but that there should be space somewhere for a steamer to turn. In some instances a steamer backing out would find herself not only in difficulty but in considerable danger.

Colonel MARTINDALE replied, that in the dock to which he had referred there was a space at one end of about 1,000 feet wide, and at the other a space of about 600 feet wide, in which a ship could turn.

Mr. ANDROS asked whether the bottom of the Whitehaven dock was puddled, and what amount of leakage took place when the gates were first shut? In the case of a dock opened a few years

ago at Workington in a similar situation, and which was not puddled, when the gates were first shut the leakage was very considerable, between 2 and 3 feet between tides, but in the course of a few weeks it was reduced to 5 or 6 inches, and it was now practically nothing.

Mr. MACKENZIE said, that Mr. Brunlees, who was unable to be present, had asked him to make one or two observations in his stead. With reference to the lime concrete used in the foundation of the dock, Mr. Brunlees would prefer, under similar circumstances, to use cement concrete, chiefly because the lime concrete set so slowly that it was apt to be injured by the action of pumping; whereas cement concrete would set sufficiently hard in twenty-four hours to resist injury from that cause. Mr. Brunlees attributed the springs met with in the foundations of the lock chiefly to rain water collecting on the surface of the lock slopes. In excavating the site of the lock the soil was continually slipping, and ultimately the slopes on each side formed a series of ridges and hollows, parallel with the line of the lock. In these hollows the rain water accumulated, and by filtering downwards obtained a head of pressure on the foundation, and upwards in the shape of springs. He was himself of opinion that the springs which occurred in the foundation of the dock wall were also due to land water.

Another point to which Mr. Brunlees had desired him to direct attention was the large sectional area provided in the sluicing ways of the lock, with a view to insure the prevention of any accumulation of silt. Those sluice-ways had answered their purpose very well. The outer sluice-ways were divided into three branches for the purpose of spreading scour over the apron, and they had proved ample. They were scarcely ever used, except to a limited extent. The scour from the sluice-ways had been sufficient, not only to clear the lock of silt, but to maintain the entrance channel. This statement should satisfy those speakers who had expressed fears as to the accumulation of silt in the lock. On this head it should also be stated that the rollers of the gates were provided with scrapers, for the purpose of clearing away the mud on the paths in front of them when they were moved. When the Avonmouth Dock Bill was in its Parliamentary stages several eminent engineers expressed very diverse opinions as to the effect of the tidal ebb and flow in the channel. Some of them held that it would be impossible to maintain that channel; that considering the great amount of mud which the water held in suspension, and the complete silting up of the north channel which had re-

cently taken place, the proposed channel would inevitably silt up. On the other hand Sir John Coode, who was the principal witness in favour of the Bill, had no fear on that head; and held that the fresh water of the Avon scouring the entrance so near the locks, at a depth of about 8 feet 7 inches below the outer sills during the period of low water, would have a tendency to suck the mud out of the channel. The experience of the last two years since the dock was opened had completely confirmed Sir John Coode's anticipations. In fact, the tendency of the channel had been to become deeper, and it was now about 2 feet deeper than when it was dredged. That result had been gained by a very moderate amount of sluicing. In fact, the result was due simply to the discharging into the channel of only about three lock-fulls of water per month. He thought these facts had an important bearing upon the question of dockizing the river. Mr. Abernethy had said, that if a dam were placed across the Avon the same result would happen as had happened to the north channel, and that it would silt up. Considering that the entrance from the channel to the Avonmouth lock had been maintained and deepened by the scouring action of only three lock-fulls of water per month, he thought that a short channel from a dam placed across the Avon to the Severn, with the unlimited amount of water that would be available for scouring, could be easily maintained. The inclination or fall such a channel would have towards the deep water in King road, and the great scour of the Severn at its entrance would conduce to the same result. He would not go into the larger question raised in connection with that matter, but would express his opinion that such a channel as would be formed in the case supposed would simply be the Avonmouth channel on a large scale. It had been objected that the scheme would deprive small craft of the advantage they now possessed in availing themselves of the flood tide to go up to Bristol. At present the small craft did not use the river in that way. They generally passed the Avonmouth dock on the flood-tide, when there was about 15 feet depth of water on the Avonmouth sills, and arrived at Bristol about an hour before the locks were opened. About 80 per cent. of those small vessels were towed up the river by steamers, and the remainder navigated the river at a considerable risk. If such a scheme were carried out, locks would undoubtedly be placed at the entrance, so that small vessels, and others of a larger size, could be admitted into the float, and sent to Bristol, at nearly all states of the tide.

With regard to the dock walls, the two great difficulties that

had to be contended with were, weak foundations and unreliable backing. The distinction between the foundations of the wall and the wall itself had been somewhat vaguely treated in the discussion. If the foundations of a dock wall were sufficiently hard to resist the maximum pressure upon them, and the base of the wall was wide enough to resist the thrust of the backing, the works to which reference had been made, such as toes and buttresses in front of the wall, would be entirely superfluous. It would be found, he thought, that the failure on the westerly side of the dock was mainly due to the soft material under the concrete footings. That material was of a very inferior description, and no such bad material was found at any other point. The clay on which part of the wall was put, and on which it was now standing, was not, he thought, the very bad material that it had been represented, because a great portion of the wall stood for seven years upon it, fully backed up and with the dock empty, without perceptible movement. With regard to the wall on the eastern side, he did not doubt that it had failed owing to the enormous increase of thrust, due to the deteriorated condition of the backing. The season was very unfortunate at the time the wall was backed. When it was fully backed up there was a prolonged season of rain, and the backing, after it had been carefully deposited, got thoroughly saturated. He would point out that the section of the east wall about the base was about 18 feet, and that base would be quite suitable to a backing the natural slope of which was about $1\frac{3}{4}$ to 1. As long as the backing did not have a flatter inclination than that, the wall was safe; but when that was exceeded by saturation it became insufficient. That, undoubtedly, was the cause of the failure. The lesson he drew from the failures and from the successes (for it should be remembered that the failures formed a small portion of the total length of the wall) was the necessity of extreme care being taken that the material with which a wall was backed could be relied on to maintain the angle of repose calculated upon in fixing the width of base. If that were done, the most economical way of designing a wall would be, undoubtedly, not to make it wide enough to sustain any amount of pressure, but to fix upon an angle of repose in the backing, and to take care that it was a backing that would stand at that angle. He believed that if the backing at the Avonmouth dock wall had been material whose natural slope was not flatter than $1\frac{3}{4}$ to 1, no failure would have occurred; and he thought it would be good economy to have the backing of walls of material whose angle of repose

would not be affected by water. Mr. Giles mentioned that he had built a wall 40 feet in height with a base of 25 feet, and that it showed symptoms of movement; and the inference he had drawn was that 25 feet was not a sufficient base for the height of that wall. That, again, was, in his opinion, entirely a question of backing. He should think in the instance quoted the backing must have been exceedingly bad material, for the width nearly approached what would be required for mud pressure, or nearly double water pressure. Mr. Giles appeared to have thought it would be a good plan, in the case of a weak wall, to remove part of the backing and substitute a platform of timber, and that counterforts were expensive and useless. But surely it would be better, instead of putting a timber platform behind a wall, which had to be renewed every ten or twelve years, to put quarry spalls or other such material behind, so that no thrust would be brought upon it, and which would form a permanent quay. He could not agree that counterforts were expensive and useless. In the last failure at Avonmouth there was no alternative but to build counterforts. The object was to get the water in the dock at the earliest moment, consequently the fracture was made good as soon as possible, and the water admitted within a few weeks of the failure. The counterforts were afterwards put in when a depth of about 15 feet of water was let into the dock. It would, he thought, be admitted, that at any rate the counterforts lessened the pressure of the material behind the wall, and that the holding power must count for something.

With regard to Mr. Browne's remarks as to the strength of dock gates, it was undoubtedly true that, when the formula "$t = pr$" was applied to a dock gate, it was assumed that the centres of pressure coincided with the centre line of the cross sections of the gate; but in a gate constructed of such material as Memel or pitch pine the factor of safety was necessarily so large, owing to the variations in the strength of the timber, and to the fact that to some extent the dimensions had to be regulated by the scantlings obtainable in the market, that it was ample to cover any deviations from that ideal condition. The formula gave as good a practical result as more complex methods. He did not share Mr. Browne's scruples as to making large gates of timber. The Canada lock at Liverpool was of 100 feet span compared with 70 feet at Avonmouth, and when this was taken into account the total pressure on the bottom ribs of the gates at these places was not very different. The settlements in the masonry at Avonmouth would have been very detrimental to iron gates, and he

believed would have caused their ultimate abandonment in favour of wooden gates. As to the decay of the timber, it should be remembered, that even in iron gates the parts subjected to the greatest tear and wear, the mitre and heel-posts, were made of wood. Mr. Giles remarked that the cost of ashlar given in the Paper was in favour of granite. This had also impressed the Author. Forest of Dean stone could not be dressed in the quarry as granite could, because, in loading and unloading, frequently before it reached its destination, the edges or arrises got chipped off and broken, which was not the case with granite. It had, therefore, to be sent to the dock works in scabbled blocks, which, in dressing to the exact dimensions required, involved more or less waste, and thus increased the cost. His experience had shown that it would be good economy to make the whole of the quoins and ashlar work of a lock of granite. Mr. Duckham thought that a vertical face should be adopted in lock walls instead of a battered face. The advantage of the latter was that, in designing the wall, the segment of masonry lying between a curved or battering line and a perpendicular line let fall in the skewback of the invert could be removed without affecting the stability of the wall, and an additional width of lock was thus obtained proportionate to the amount of batter. The avoidance of accidents on account of a battering wall was a matter of care on the part of the dockmaster. Mr. Duckham had reminded him that he had omitted to state in his Paper that hydraulic machinery was provided to move the lock gates, capstans, &c., and that three fixed cranes capable of lifting 35 cwt., one movable crane of the same power, and one 15-ton fixed crane, had been provided on the quays and worked by hydraulic machinery. The latter was supplied by Messrs. W. G. Armstrong & Co., and was of their usual type of appliances for dock purposes. With reference to the remarks of Mr. Giles as to the width of the dock, he might state that the Avonmouth dock was 500 feet wide; so that a steamer of 450 feet in length, or even 480 or 490 feet, would have no difficulty in turning round, because if any vessels were lying in the way they could easily be shifted.

Mr. WILLIAMS observed, in reply, that as Mr. Hayter had been good enough to say that the works at Whitehaven had been a complete engineering success, it was not necessary for him to make any lengthened remarks, but there were one or two points to which he desired briefly to allude. With reference to the load on the swing bridge; owing to the limited area of the site the tail end of the bridge was unusually short, and in this case a load of

5 cwt. at the extreme end of the long arm was considered ample to prove the stability of the structure while turning freely upon its pivot. The bridge was also tested, when closed, with a moving load of nearly 1 ton per lineal foot, but the flange strain was then considerably less than during the previous test. Mr. Parkes was anxious that something should be said more in detail as to the causes which led at one time to the silting up of Whitehaven Harbour. Of course in connection with harbour works it would be manifestly absurd to generalise, but in many instances it would be found that when a solid pier was run out from a sandy foreshore, and intercepted the littoral currents, accretion ensued in the vicinity of the pier, and the low-water mark gradually advanced seaward with the advance of the structure. At Whitehaven the set of the tides was peculiar. As the flood tide set from the southward a counter-current set towards the harbour from Redness Point; and as the construction of the west pier advanced seaward it intercepted this current, and in consequence deposition ensued within the shelter of the pier. Sir John Rennie, seeing this, impressed upon the Trustees of the harbour the necessity of at once proceeding with the construction of the north pier; and there was no doubt that if his advice had been followed the harbour would not have silted up to anything like the extent it had done. He might add that the natural shoaling tendency of the harbour had been much diminished by the works recently carried out by Mr. Brunlees, and described in the Paper. Prior to the construction of the north wall there were three openings in the north pier, and the consequence was that the counter-current from Redness Point set directly into the harbour, carrying with it sand and other matter in suspension from the adjoining shore. By the construction of the north wall these openings were demolished, and the consequence was, that while the secondary outlet was closed the scour of the harbour was materially increased, because the ebb water could now only escape through one outlet direct down the fairway to sea. As to the general question of dockizing tidal rivers in the interests of navigation, he should regard any proposed works tending to diminish the tidal volume of a river with some suspicion; and he was inclined to think that if the river Avon were dockized, the 6 feet depth of water which Mr. Mackenzie had stated to be now in the Swashway, at low water, would rapidly disappear. Reference had been made to the form of locks, and the desirability of docks being made wide enough to enable the largest class of steamer to turn round, instead of undocking stern foremost. No doubt that was a matter of import-

ance where the seaward channel was contracted and tortuous, like the Avon itself. But in the case of Liverpool or Hull, and probably Avonmouth, undocking stern foremost was, he thought, a matter of secondary importance compared with the advantage of extra quay berths inside. The turning of a modern ocean steamer in dock not only necessitated a considerable mechanical expenditure, but also the shifting and inconveniencing of other vessels in dock; and, from observations at Liverpool, he could state that it was a very common thing for large steamers to undock stern foremost. A subject of considerable importance in connection with harbours and docks had been touched upon by Sir John Coode, and that was the great change that had come over the character of our shipping, and which would have to be considered with reference to the proportions and details of modern docks. Steamers were now not only twice as numerous, but twice as large, as they were fifteen years ago. This increase of tonnage in the modern steamer was not so much due to increased depth or beam, entailing deep and wide entrance locks, as to increased length; so that, instead of providing dock accommodation for the short bluff type of vessel, engineers were now required to afford accommodation generally for vessels long and thin in character, in some instances exceeding 500 feet in length. When engaged at Liverpool, under Mr. Lyster, lock entrances were constructed 100 feet wide, to accommodate such vessels as the 'Scotia,' the 'Persia,' and the other paddle steamers of the Cunard line; but for ocean service the paddle-wheel was a thing of the past, and a lock 60 feet in width would be ample to admit the largest modern steamship in the mercantile marine. With reference to the form and batter of dock walls, no doubt with a given mass, a battering face materially increased the stability of the wall, but there was a limit for the batter, particularly in a tidal harbour. If a batter of 1 in 12 were exceeded, a vessel might get nipped, during the fall of the tide, between the face of the wall and a deeper laden vessel. He was of opinion that in tidal harbours a batter of 1 in 12 should not be exceeded, and if possible the foundation should be inclined normal to the batter; but in the case of dock walls, or where vessels lay afloat, the batter of the face of the lower portion of the wall might be increased with advantage. He was further of opinion that the face of dock walls should be built slightly concave or arched on plan, which would not only give them increased stability, but, in the event of their moving forward, it would be towards a straight line instead of away from it. He agreed with Mr. Giles that dock walls should be sufficiently

strong to resist their maximum head of water while unsupported in front. As to borings, he thought it was very important that they should be made outside the line of the work. If they were made within the line of the wall, they might during the progress of the works lead to considerable difficulties, simply because they tapped the springs. He had found that by experience, and he had therefore advised that when borings were required they should be made at a short distance from the proposed work. The cost of the dock gates at Whitehaven to the Trustees had been 12*s.* 1½*d.* per square foot. With regard to the leakage, at Workington dock, which was said to be about 3 feet between tides; at Whitehaven the bottom of the dock was not puddled, and the maximum leakage between tides at first did not exceed 6 inches, and at present it was almost nil. The areas of the two docks were about equal.

Mr. WILLIAM J. DOHERTY remarked, through the Secretary, that the "striking example" of "mud settlement" at the Avonmouth dock, which had been attributed to a "variety of causes," could be easily accounted for, if an examination of the surrounding river and tide-way were made. Where "mud settlement" had been recent, it followed that there must have been some diminution, or alteration in the quantity or direction, of the water or tide-way—a point sometimes lost sight of in the curtailment of water areas, particularly in their relation of assisting in the dispersal, or preventing the accumulation, of silt in the channel ways of riverless harbours. A practical example, illustrative of this view, was that of the Lough Swilly Reclamation Embankments, cutting off from the Lough some of its shallower estuaries, upon which he had been engaged in 1856. The embankments joined the southern end of the island of Inch to the mainland, thereby preventing the tidal waters from flowing over a shallow slob-land of about 3,000 acres. Thus the north-east channel, for a distance of nearly 3 miles from the embankment, had been silting up for the past twenty years, and, from having a depth, in 1856, of 4 feet 6 inches at extreme low-water, at the point where the embankment crossed the channel, it had been silted up to 3 feet 6 inches above low water for fully 1 mile, and no channel now existed at low water for this distance. The remainder of the 2 miles of channel had been affected, so that oyster-beds, formerly highly productive, had become almost useless from the silting up. Again, the channel on the western side of the island had fared no better. At the Farland Point, where there was formerly a depth of from 16 to 18 feet at low water, the depth was now only 6 or 7 feet, notwithstanding there was but little silty

matter apparent in its waters. This showed that the curtailment of water areas behind the channel was deleterious to the navigation.

It was a distinguishing feature of fine sand foundations, where the substrata communicated with the adjoining river, that trouble was to be expected from what the Author termed "springs," but what were in reality the filtrations of the adjoining waters through the sand. This appeared to have been the case in the Avonmouth dock, where, the Author stated, "the clay bed left the sand exposed at 6 feet below low water," which was also the "level of the bed of the Avon near the dock," so that the sand formed a filter-bed, through which the water found its way. Similar examples had come under his observation, as that of the Hamilton graving dock, Belfast; and, notably, that of one of the graving docks off the Great Float at Birkenhead docks, which had to be abandoned as a graving dock in consequence of "springs" or filtrations. Every application usually resorted to in such cases had been adopted by Mr. Lyster, yet the "springs" obtained the mastery. The reference to the quantity of water escaping at low water, in front of the outer invert of the Avonmouth dock, was a confirmation that the water from the dock filtered through the sand bed. He believed that if a layer of from 2 to 3 feet in thickness of small broken stone and fine gravel had been laid over the surface, before building the masonry of the invert, sill, or walls, the "spring" would thereby have had the means of travelling to the artificial ducts left in the masonry, without carrying away the sand in sufficient quantities to damage the foundation bed on which the masonry rested; and he thought that the bottom courses of either masonry or concrete in weeping foundations should be laid with Portland cement, in preference to hydraulic lime, on account of the quickness of setting.

From the uncertain depth of the foundations below the dock floor, it was evident that there was great irregularity in the form and dimensions of the structure; and the founding on a bed of "blue clay," of alluvial formation, overlying a bed of fine water-bearing sand, must have arisen from an economical mistake. It was a hardy experiment, to risk upon such a foundation a wall 40 feet high above the floor of the dock, and built of such top-heavy proportions as described. He considered that the inclination of the wall to overturn, by coming forward at the top, was attributable to the over-thickness of the masonry at the top; and that the concrete pockets had been wisely abandoned.

One of the most important elements in securing the stability of dock walls, was the care with which the filling and its quality

were attended to; a little extra expense in procuring rock rubbish, or quarry shivers, for filling immediately behind walls, would insure the non-lodgment of water, during their construction; and as the quarry reddings would exert no weight on the wall, being self-supporting, the pressure of the remaining filling would as a consequence be reduced to a minimum. The faults in the Avonmouth dock walls had been increased by the want of caution in ascertaining the nature of the foundations, and by the use of defective backing. However, the Author was to be congratulated upon the unreserved manner in which he had given an account of the failures, as too frequently weak points were kept out of view.

The proportions of cement concrete used would, he fancied, have been better if 2 parts of the sand had been kept out. He was of opinion that the ordinary pug-mill form of mixer placed horizontally, as introduced for concrete mixing by Mr. B. B. Stoney, having revolving knives, was much superior to any other form, considering that if well attended it could turn out from 60 to 70 cubic yards of concrete in a day. Hand-work should only be applied to concrete made of hydraulic lime, where the relative proportions of the materials were not very different.

No port in Ireland had become of so much importance, within the same space of time, as Belfast. He considered it fortunate for the progress of the port that the schemes of Messrs. Rennie, Telford and Rhodes had not been carried out. A ship canal in a harbour with an average rise and fall of tide of only 8 feet would have been a decided inconvenience. As one of the contractors for the construction of the Abercorn basin and Hamilton graving dock, opened in 1867, under whose personal supervision the works had been carried out, and also as contractor for the construction of the Queen's quay, opened in 1877, he was conversant with the whole of the improvements recorded by the Author, and consequently regarded the general prospective improvements with much interest. Looking to the progress made at other harbours towards meeting the requirements of modern shipping, namely, having a deep-water entrance and harbour for all states of the tide, the Author's view of obtaining a depth of 15 feet below low water was moderate, and therefore the improvement of the approaches became a necessity. He thought that any deepening for the improvement of the fairway of the channel approach should be in the direction of making it straight through from the Twin Islands to the 3-fathom line of soundings, at a point opposite, slightly to the north-east of Holywood; and that the first operations should be from the 3-fathom sounding in the present channel east of the middle bank, and

across the Holywood bank. If this were done it might be found that much of the present inconvenience would have been overcome; if otherwise, then the deepening through the present middle bank north-west of the Stone beacon could be proceeded with. No danger need be apprehended from the "send" of the sea, even should the straight channel have to be adopted in its entirety, as the distance to the inner harbour from the Holywood bank exceeded 2 nautical miles. One great desideratum for all harbours was a uniform and uninterrupted approach, affording a clear outlet to the ebb tide and back water, and thereby making the channel its own dredger.

The Hamilton graving dock and Abercorn basin were founded on a bed of sand—firm and compact when kept clear of water, but quick when under its influence. The same difficulties were met with here from "springs," or rather filtrations, as were encountered at the Avonmouth dock, with this difference, that the pressure at the Avonmouth was due to a head of 44 feet at high water, while at Belfast it was only 24 feet. Consequently the pressure on the sand bed was much less at the latter place; yet, after the floor of the graving dock had been laid in hydraulic lime concrete and close-jointed ashlar pavement, the "springs" burst out in various places. Numbers of safety pipes were inserted into the floor of the dock as near the sides as possible, and grooves were cut to lead the flowing water into the side channels. After grouting under pressure the fine sand ceased to come up, and the water had since flowed freely with slight diminution, thus saving the floor of the dock from "blowing," and the masonry from being cracked.

A slight settlement in the pump-well, engine-house, and adjoining pier-head, had taken place, not so much attributable to the sand flowing away underneath as to the insufficiency of the foundations, both as regarded the thickness of the masonry, particularly as to its depth, and the nature of the strata upon which it rested. At this place a fault existed in the uniformity of the sand bed, the blue clay alluvial deposit overlying the sand. No doubt from the desire of not incurring extra expense, the foundations had been more tenderly dealt with than subsequent experience showed would have warranted. The remaining walls, sills, floor, and apron of the graving dock, and walls of the Abercorn basin, remained as perfect as when they were built, being straight and sound throughout. Care was taken to preserve for filling the best of the excavation, consisting principally of fine sand deposited in uniform layers in a dry state. The basin walls were built of "snecked" ashlar, sandstone facework up to the level of low water, with fine-punched

whinstone facework above that level, the backing throughout being chiefly sandstone. The whole was laid in hydraulic lime mortar, made from Flintshire blue lias stone, burnt and ground on the works. The compactness of the sand bed, into which the elm sheet piling of the new Queen's quay had been driven, necessitated the continuous work of a self-acting endless-chain steam pile-driver, actuating a 2-ton ram from four to seven hours, to drive a set of three 37-feet piles. The only thing to be regretted was that, with such firm foundations, the stone walls of the Abercorn basin had not been continued for the 2,150 feet to the bridge instead of the new Queen's quay timber wharf, notwithstanding the excellence of its design.

It was questionable if the saving of cost in the first instance would make up for the inconvenience of renewal thirty years hence. The cost of the graving dock and basin had been about £60,000, and of the Queen's quay wharf about £58,000. These were the only works at the harbour with which he had been personally connected.

He had many opportunities of examining the failures at the Dufferin and Spencer docks and entrance. The Author of the Paper pointed "to the weakness of the piling timber, and the inefficient depth of footings," as the cause of failure, combined with the soft filling "behind the walls." With this opinion he to a great extent agreed. Sometimes a sense of economy prevented young engineers from designing works in doubtful foundations sufficiently strong, particularly when dealing with clay deposits, such as those under notice both at Belfast and Avonmouth. Round timber piles with tapering points, 15 feet long, 4 feet 6 inches apart from centre to centre, and only 7 inches in diameter at the small end, had been clearly a mistake where 28-feet piles, each 12 inches square, had been driven by the Author in rebuilding the fallen entrance. If, in the first instance, whole-baulk piles, 12 inches square, 3 feet 6 inches apart from centre to centre, had been driven 5 to 6 feet into the sand bed, and a row of 12-inches square sheet piles of the same length had been used, together with a depth of 6 feet of concrete instead of 18 inches, and the section of wall had been slightly increased up to the level of the second set-off from the bottom; and if a 6-feet thickness of quarry shivers had been placed behind the wall as a first filling, and the remainder of the filling had been selected with ordinary care, there was little doubt that the walls would have stood without failure.

With regard to the Whitehaven dock, he would only notice the mode of building the walls—with front and back divisions, having an intermediate space of 4 feet, called "pockets," for concrete. He

thought it would have been better to have built the walls solid, as no saving in labour or materials could have been effected, and only a weaker wall had been obtained; however, the use of rubble and the reduction afterwards of the width of the wall from 9 to 6 feet underneath the coping was a decided improvement.

As one who tendered for the construction of this work at £101,220, it was a confirmation of his views of the value of the work to be told that the actual cost had been about £100,000.

Mr. J. P. GRIFFITH observed, through the Secretary, that the contest whether Belfast should be a closed dock or an open port had been carried on with great ability by the supporters of the several schemes. Fortunately, the proposal to construct a ship canal with entrance locks was rejected, and the port had thus been left freedom for expansion to meet the unknown wants of the future. The approach to the harbour still required considerable improvement; but, from the apparent desire to reclaim slob land, it would seem that the difficulties of constructing and maintaining a deep-water channel much farther down the Lough were not at present fully realised. It was admitted that the foundations on the south side of the river were good, while those on the north side were treacherous, and with this in view it would be interesting to know the reasons which induced the Author to adopt the same method in renewing the Queen's quay as had been carried out at the Albert quay on the opposite side of the river. A paper on Belfast Harbour, read by the Author before the British Association in 1874,[1] furnished the approximate cost of the Albert quay. The length of the quay was there given as 1776 feet, and the probable cost at completion £50,000, or about £28 per lineal foot. The amount charged in the annual accounts of the port to the renewal of the Queen's quay exceeded £62,600, or about £29 per lineal foot. This seemed a high price for work of the kind constructed on a firm foundation, affording at best the comparatively shallow berthage of 16 feet at low water, and the life of which could not be expected to exceed thirty years. From the substitution of American elm sheet piles, in place of pitch pine as used in the Albert quay, it would appear that a foundation difficult of penetration had been expected. Taking into consideration the circumstance that the new line of quay was considerably inside the old, and that no cofferdam would have been required for the construction of a masonry wall, such a quay could have been built at very little extra cost. Special reasons may have led to the adoption of a timber wharf on this

[1] *Vide* Report of the Forty-Fourth Meeting, p. 118.

site, but, without some explanation on the point, it might be thought the failure at the Spencer dock had shaken confidence generally in masonry walls. He could not entirely agree with the Author as to the cause of this failure. The fact that "the wall fell outwards at the top, and, revolving on its toe, broke the bearing piles across," confirmed his opinion that the wall section was too light, and that with such filling as described, it would have overturned, no matter what piling was below it.

Sir CHARLES HARTLEY communicated, through the Secretary, the result of his personal examination of certain quays of modern construction abroad. He visited the great Italian naval station of Spezia, in December 1865, when he had the privilege of being

FIG. 4.

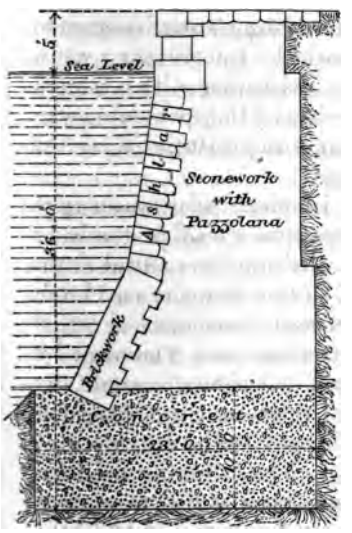
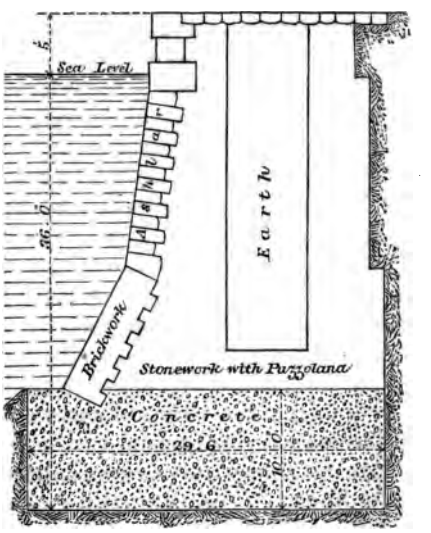



FIG. 5.




conducted over the site of the two newly-projected government docks by the late General Chiodo, the chief engineer of the works. The construction of the first dock was then in full progress. According to General Chiodo, experiments to ascertain the true nature of the ground, which was composed of sand, silt, and clay, in varying proportions, had demonstrated the necessity of building the dock walls of unusual thickness, to prevent them slipping forward by pressure from behind, which experience had proved would be exceptionally severe. The quays of the two docks had an aggregate length of 7,216 feet. Two sections (Figs. 4 and 5) were adopted, (Fig. 4) for about a third of the whole

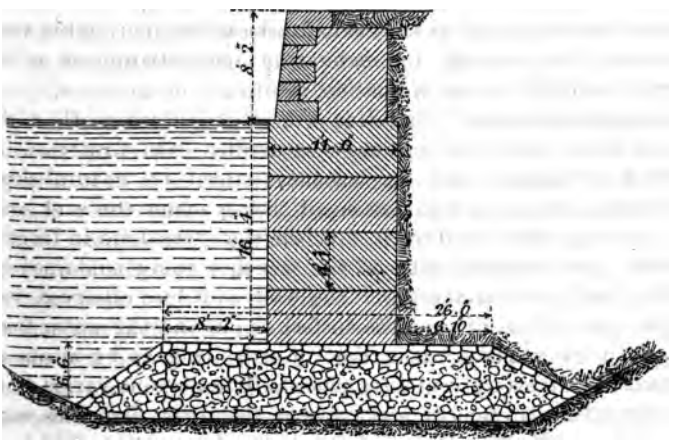
length, where the bottom was comparatively solid, and (Fig. 5) in soft ground. The walls were 41 feet high throughout. It would be seen that in section (Fig. 4) there was no open work, and that the base was 23 feet wide. In the section (Fig. 5) there were pockets or wells, which were afterwards filled with earth, 15 feet long, with division walls 5 feet thick between them. The base of this section was 29½ feet wide. In both sections the bottom was shown to touch the foot of the wall at 26 feet 3 inches below the water-line; but, in reality, the ground sloped off directly from that depth to 32 feet 9 inches, which was the depth of the docks below sea level. The interior walls were built dry in trenches; but the walls facing the sea, at the entrance to the docks, were constructed by passing puzzolana through the water in the usual Italian fashion. The mode adopted of first building the walls, and then letting in the water, had the great advantage of enabling steam dredgers to excavate the docks below the levels reached by ordinary means. The total expense of dredging, and discharging the material dredged, was estimated by General Chiodo at 10*d.* per cubic yard, or only half the estimate for excavating and getting rid of the material, without the use of floating plant.

The system followed in building the interior dock walls might be thus described. The necessary excavation was first made to 13 feet below the sea level, leaving the earth at its natural slope. Then, having to lay the foundations at 36 feet under the said level, and to cut through a muddy stratum, the work was done in lengths or sections, the vertical sides of the trenches being sustained by boarding and heavy timbering. The wall, as before observed, was built dry, on a base of concrete 10 feet thick, and the water from infiltration was pumped out of the timbered lengths by means of hydraulic machines conveniently placed. The sections varied from 26 feet to 33 feet in length, and between them like distances were left, and were filled in afterwards, when the first sections had been raised to a certain height. In other words, the sections of wall up to a height of 23 feet were divided from each other in the first instance by sections of undisturbed material, by which means the treacherous nature of the ground was more easily dealt with. The concrete foundation of the dock walls was composed of two parts of puzzolana to one of lime and three of broken stones, thrown down from a height of upwards of 30 feet, and cost 15*s.* per cubic yard in place. The body of the walls was of rubble set in puzzolana, and the facing of bricks and ashlar; the former being more convenient to handle than ashlar in the close timbering of the trenches. Since the works were completed, only a slight settlement

of the walls had been observed in a few places, but they had nowhere been thrust out of the perpendicular. This result, which had been obligingly communicated to him by Mr. George Furness, Assoc. Inst. C.E., indicated that if careful precautions were taken in the erection of dock walls on ground peculiarly liable, as at Spezia, to slips, and if a sufficient weight was given to the wall to sustain unusually great lateral pressure, an almost certain immunity from failure might be secured, without resorting to the use of bearing piles—on the efficacy of which he thought too much dependence was often placed—or to backing of a very expensive kind.

He considered that the Authors of the Papers on the Avonmouth and the Belfast docks were deserving of special commendation, for the clear and candid manner in which they had related the details of certain failures in the dock walls built under their personal superintendence. They had attributed these failures princi-

FIG. 6.




pally, if not entirely, to the employment of faulty material for backing, no better being near at hand. It would be presumptuous in him to attempt to criticise this explanation, as he had never seen the ground. It appeared to him, however, that the experience gained in the recent construction of dock walls in this country might be usefully compared with that which had been obtained at Spezia, and also with some other systems of building quays which had lately been practised by Continental and English engineers in foreign countries. To three such instances he would now briefly refer. At the mouth of the Rhone, facing the river entrance to the St. Louis maritime canal, the quays (Fig. 6), were composed

of four concrete blocks, each 11 feet long, 8 feet 7 inches wide, and 4 feet 1 inch high, built on a base of *pierres perdues* 26 feet wide and 6 feet 6 inches high. This concrete wall was surmounted by a superstructure of rubble, faced with ashlar, 8 feet 3 inches in height, and 9 feet 6 inches wide. The total height of the wall, therefore, from the coping to the bottom of the dredged trench, was 31 feet, its width being 11 feet, the length of the blocks. The latter were similar in every respect to those employed at Marseilles,[1] and cost 18*s.* 6*d.* per cubic yard in place. The total cost per lineal yard was £48, including dredging, staging, and provisionally loading the concrete wall with tiers of blocks before adding the superstructure, a precaution against undue ultimate settlement now universally adopted in similar structures by French engineers. At the new harbour at Alexandria, carried out by English enterprise, instead of building continuous quays in deep water for the accommodation of large vessels, the system of projecting short jetties from the shore to deep water at convenient intervals had been adopted. These jetties were about 80 feet wide, and extended about 40 feet from the shore or top of the slope, which had an angle of about 45°, and was pitched with stone. The face of each jetty attained a depth of 30 feet of water, and its superstructure was supported by three iron cylinders 5 feet in diameter, sunk, in 6-feet lengths, by pneumatic barges and divers, until they reached the rock, at a depth varying from 60 to 70 feet below the water line. On the land side, the superstructure of the jetties rested on a concrete wall founded on the top of the slope. In the Hooghly, at Calcutta, Mr. W. D. Bruce had carried out with marked success extensive jetty works of malleable iron screw piles, a mode of construction extremely well adapted to soft and sandy strata in a waterway liable to be inconveniently silted up by the projection of solid works, opposed to the free flow of a current highly charged with alluvion. He had no information regarding the details of the harbour improvements referred to at Alexandria and at Calcutta, but he was satisfied that Papers giving a full account of these important works would be highly valued by the members of the Institution.

Mr. W. Redfern Kelly remarked, through the Secretary, with reference to the failure of the masonry walls of the entrance to the Spencer dock, that, independent of the question of the weakness of the piling timbers, the insufficient depth of the footings, or the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxiv., p. 144.

unsuitability of the backing-up materials, in the present case the wall section was rather light; and that even had the bearing piles not given way in the manner described, the wall would eventually have been thrust forward in a lateral direction by the weight of the filling-in material behind it. This opinion was strengthened by the fact that the walls of the Spencer and Dufferin docks in various places had bulged outward; in some cases at and from the toe upwards, whilst in others the symptoms of weakness were only visible at or near the level of low water. In many places these settlements, which were indicated by a bulging outwards of the work and by vertical and zigzag fissures in the masonry, extended from the coping to about one-half, and in some instances one-quarter, the depth of the wall, whilst in others they extended from foundation to coping. This bulging out of the walls varied in extent, being only visible in some places for a length of about 10 feet along the wall, whilst in others it extended over a length of upwards of 50 feet. Some of the settlements, which were chiefly lateral, had taken place prior to the tidal water being let into the docks, and whilst the walls were "green" or unseasoned. After the water had been admitted to the works it was found that its counter-pressure checked, to a considerable extent, the outward tendency to settlement of the walls; and it was only then that the backing up of the work could be completed with safety, an operation which had to be conducted with the greatest caution and attention. In dealing with a foundation subsoil similar to the instance above referred to, he considered that, for an artificial foundation, instead of round piles, heavy square timber should always be adopted, and those piles driven with a slight batter. Not only should the footings be deeper than ordinary, but the section of the wall should be materially increased, especially when the engineer was aware prior to designing the structure that he had to deal with a material for "backing up" which was most unsuitable for that purpose, and that he had, as well, to contend with a soft, pulpy, yielding subsoil immediately in front of the intended wall. Further, instead of making the platform on the top of the bearing piles horizontal, it should be laid at an angle of 90° with the battered face of the wall, the latter being not less than 1 in 12, or perhaps more than 1 in 18. Also, the masonry courses of the wall should be laid parallel to the platform; and the walls of docks should where practicable be built with a slight camber.

Mr. WALMSLEY STANLEY observed, through the Secretary, that Mr. Abernethy had, in reference to Whitehaven and other places,

raised the question of the influence of the projection of piers into a tideway, across a foreshore; but he submitted that the present Papers did not refer to such a subject. He also dissents from the opinion of the value to be derived by discussing such histories of failures as were recorded in the two first Papers. There were, no doubt, cases where a correct history of a failure of works might be of the highest importance; as, for example, when some new element, or combination of elements, of danger and difficulty had been met with and successfully overcome; but there was nothing in these Papers that brought them within the above category of usefulness.

Referring to the Avonmouth dock, 18 inches above equinoctial spring tides for the top of the temporary dams appeared to be a small margin for safety. As regarded the locks, he considered the foundations to have been exceptionally good. The difficulties with the springs had been created by the mistaken idea of trying to weight them back, thus driving them hither and thither, till the whole surface of the foundation was disturbed. Where it was found that so thin a layer of clay kept back these springs, he saw no reason why it should have been removed. Had the whole area of the foundations been surrounded by sheeting, then excavated and filled to the requisite depth with hydraulic concrete, and the springs carried up with and over the work by pipes, to such height as they ran free of sand, and the water kept from the concrete till it was properly set, no difficulty ought to have been experienced. Cast-iron paddle-frames, especially in conjunction with brass faces and salt water, seemed a bad and costly arrangement. The settlement of the recess and the rising of the outer platform appeared to be due to no invert or extra thickness of foundation having been carried below this vital part. The idea of the Author that the settlement of the recess was partly the cause of the rising of the platform could scarcely be correct, as this latter did not appear to have commenced till some time after the settlement. The connection between the pressure of the tide on the outside of the apron and the first rising of this platform, and the fact that when water was admitted into the lock the platform sank again to its former level, appeared just; but it conveyed to his mind the possibility that some day, when the gates were shut, and a heavy pressure was retained inside, there would be danger of a "blow" under the sill. He thought that the water "which has burst up behind the row of piles in front of the outer invert, and has brought up a quantity of sand from the bottom between the piles and the masonry," was indicative of some such action. He

presumed that the roller paths had been relaid 3 inches lower, to restore them to the level they occupied before the rising of the platform of which they formed part; but no description had been given of how this important and interesting work had been carried out. It was stated that a roller path had been added after the rising of the platform, to support the mitre post and outer end of the gate, and that the roller for the latter "was not made adjustable." How then, he should like to know, were the gates supported, when "after the admission of the water, the roller paths have slowly sunk to their former levels"? With a shaky gate recess, a platform that oscillated backwards and forwards as the water was in or out of the lock, and a gate with a flexible nose and an inadjustable wheel under it, he could not assent that "the admission of the water made everything safe." He did not see how repairs were to be effected in the upper pair of gates and platforms, as no provision for placing a caisson above them had been made; and to run the water out of the dock would probably cause serious failures in the dock walls. As regarded the lock gates, sound, lasting and rigid work could not follow the use of woods of different densities in such a situation. The suitability of the material in this case depended upon the extent of sea exposure, and whether the *teredo navalis* or other destructive insects existed in the water. Information on these points had not been given. Memel and other light timbers were objectionable, as their low specific gravity rendered them liable to be torn from the hollow quoin fastenings. Having the back of the gate a continuous circle of so sharp a radius caused several disadvantages, especially as regarded wooden gates; it necessitated the employment of compound ribs, extra weight of bolting, strapping, and bracing; deeper gate recesses, and obstruction of the quays, as well as unnecessarily heavy fender and filling-up pieces to maintain the continuity of the face of the lock and entrance walls. It was difficult to brace such a structure, and with so much belly overhanging, the gate did not travel steadily. By attention being drawn to the curvature of the sill, to the laminated ribs, and their butt joints, and by the calculations, the Author appears to have treated the gates as if they were a fixed laminated arch, and to have conceived this was an improvement on the old system. It was remarkable, however, that in the works at Whitehaven, designed by the same engineer four years later, the usual straight sill and gates had been reverted to. The middle and outer gate seemed to have been constructed according to a design in use at the Liverpool docks. He believed the system was first devised by the late Mr. Jesse Hartley, twenty-two years

ago, for the long gates for a 100-feet lock; but the necessity or economy of adopting such a type for a 70-feet entrance was not apparent. It was stated that "when a gate was moved on its roller" "it did not stand plumb, but hung forward to the extent of 14 inches," and this notwithstanding the gates were "thoroughly braced and tied by wrought-iron straps, bolts, and timber walings;" and "that in order to obtain a good mitre joint, a small roller," "not adjustable," was placed under the mitre post, "and an additional roller-path laid down for it to run on." No cause was assigned for this failure, nor was it stated whether one of the, or all the gates, were similarly affected; but such a striking, and, to him, unheard of experience, needed full explanation. He dissented from the rule laid down for fixing the position of the rollers, the effect of which would be to bring the whole weight of the gate upon the rollers, instead of dividing it so as to place half on the pivot. That the gates had been worked since with ease was doubtless due, not to the position of the roller as designed, nor to the assistance of the additional one placed under the mitre, but to the buoyancy of the pine ribs. Here again there was a remarkable difference in the designs of the same engineer; for whilst at Avonmouth a rule had been given which threw the whole weight of the gate on the roller, at Whitehaven the roller was so placed as to take about half the weight of the gate. Referring to the 100-feet dock gates at Liverpool, Mr. Browne had expressed an opinion that they, as well as gates generally, would be better built of iron. But experience had shown that at Liverpool the action of salt water mixed with sewage speedily reduced iron to such a state that it could be cut like plumbago, and that galvanising added only about two years to its life. Generally, from its superior elasticity, solidity, longevity, and cheapness, preference must be given to wood in such situations.

Before designing the dock walls, the exact nature of the strata in the line, and for some distance on each side of the walls, should have been ascertained. Nothing of this kind appeared to have been done until after the failure of the west wall. The reasons given for the failure of the west wall did not appear conclusive; and no explanation had been advanced for the greater failure of the east wall, where similar causes of failure were not found. All these movements in the wall were clearly traceable to the improper nature of the backing employed, to the haste with which "the stuff immediately in front of the wall was" "lifted up in skips and barrows," and "tipped behind," and to the fact "that though numerous weep holes were left, the water drained imperfectly

through them, completely saturating the clay" backing. Had layers of faggots been laid against the back of the wall, and layers of faggots and coarse gravel alternated with the beds of clay filling, or other similar expedients been resorted to with due care, the wall would have stood, as portions of it did, nearly fully backed up, for seven years. He agreed with Mr. Giles that it was weight not bond that was of the greatest importance in a dock wall; but no reasonable extra weight would have secured these walls against the treatment they received. It was instructive to remark how walls of equal height and lighter section stood at Whitehaven, although on worse foundation. The remedy of piling behind a wall in movement was a dangerous one, and the small footing of "4 feet by 4 feet" must have been quite inoperative. No description had been given of the formation of the south slope. The total cost appeared to have been very heavy. Looking back at the result of all the operations—with an area laid bare by being enclosed within artificial dams, where the work could be carried on leisurely and systematically, free of all tidal interruption—with a capital foundation of clay and sand, and with little water from springs or leakage—with all these advantages, what were the results? Failures in the wing wall, in the apron to the lock, in the recess of the outer pair of gates, and in the platform of the gates, and in the dock gates; failure, more or less, of all the dock walls, and of the warehouses on the quays.

The questions for consideration then were:—First, were these failures through any new elements of danger, or new combination of elements, or did they arise from want of proper examination before the design and execution of the work? Secondly, the failures having taken place, whether the remedies were such as by their ingenuity and completeness could be recommended as examples to be followed. In his opinion not a single element of danger was new, or which by ordinary care and foresight and every-day appliance should have resulted in failure. Nor did he find that a single one of the failures recorded had been remedied.

With respect to Belfast harbour, the foundations for the dock walls were no doubt exceedingly bad, as indicated by the low inclination at which the slopes had to be taken. The breaking of the piles was not, in his view, a proof that they were too light, but that when the forward movement at the top of the wall took place an undue weight had been thrown on the front row of piles. His impression, after studying the very general description given by the Author, was that here, as at the Avonmouth docks, the failure was due to the improper nature of the backing placed

behind the walls. Could any other result be expected from using a "pulpy semi-fluid mass"? If a properly-disposed filling of brushwood and turf, in layers, had been used for some distance back from the walls, he thought they would have stood without movement. Looking to the large amount of excavations in slopes in such material, he thought the stereotyped form of dock wall could well have been departed from. For example, rows of brick or iron cylinders could have been sunk before making any excavations; and afterwards the cylinders themselves, and the spaces between them if necessary, could have been filled with concrete; or the wall might have been built in sections on a crib and sunk by pneumatic pressure. Here again, as at the Avonmouth dock, the counter hydraulic principle of letting in the water to support the walls had been used, but with only partial success. The Dufferin tidal dock entrance, 60 feet wide, must, he presumed, have been carried out at the same time as the walls described; but no description of this, the most important part of the work, had been given. He noticed also that there was no statement of the cost of the various works, with the exception of the timber-wharf facing, after the designs of Messrs. Walker and Burges in 1847. He considered this Paper afforded little useful information of the works it professed to describe. The only part where details were entered into was as regarded certain failures in dock and entrance walls, but even these were not represented in such a way as to make it intelligible how such designs came to be adopted. The failures were not shown to be attributable to any new elements of danger, and the way they were overcome did not afford any example for the profession.

The Paper on the Whitehaven docks contrasted favourably with the two former, inasmuch as everything was referred to under special headings in a clear and succinct manner. The designs and mode of carrying out the work seemed to have been carefully considered, and, notwithstanding many difficulties, it had been successfully executed in a short time. One failure of slight extent occurred, and the workmanlike way in which it had been met served as an indication of the ability which had guided the other portions. It was not, however, explained why the sill of the other dock entrance was made flat, whilst an invert was used in the chamber; and it would be interesting to learn why pitch pine was used in the gates, and if it was creosoted, as he believed the *teredo navalis* existed at Whitehaven.

Mr. STONEY observed, through the Secretary, that, notwithstanding the dearness of iron in 1873, he doubted the advantage or

economy of timber for the gates of the Avonmouth dock. It was stated that 42 tons, or one-fifth of the weight of each pair of gates, was iron—no doubt for the most part in the form of expensive forgings, as their cost appeared to be about £50 per ton, which would have paid for double the weight of plated work, even in 1873. Considering, however, the durability, strength, stiffness, freedom from worm, and simplicity of construction, of iron as compared with timber, in large gates, the advantage was altogether with the former. As to durability, the iron gates of the large graving dock in Dublin, of 70-feet span, were now more than twenty years old, and apparently were nearly as sound as ever, with the exception of the timber joining pieces at the heel and meeting posts and the sill, which were completely honey-combed by marine worms, and would shortly need renewal. Properly-designed iron gates would not have overhung or become deformed in the manner described in the Paper; and the remedies which had been adopted, viz., additional rollers and roller paths, always gave trouble; they were difficult to keep clean and in order under water, and were especially so in the case in point, on account of the critical movements in the floor of the gate chamber, a matter which would probably give great trouble some years hence when the gates needed extensive repairs or renewal. It had generally been the practice, following precedent, to support large gates on roller paths; but this was by no means necessary, or indeed desirable; for iron gates might be supported by the pintles alone, like an ordinary house door, and when thus hung their friction was greatly reduced and the cost and trouble of rollers and roller paths were avoided. About five years since the roller and roller path of one leaf of the Dublin graving dock gates above-mentioned got out of order, causing excessive friction. Instead of going to the expense of repairing them under water, he adopted the expedient of tying back the upper pintle by strong wrought-iron anchor bars with adjusting screws, and lifting the roller so that the weight of the gate did not bear on the roller path. The result was that this leaf was far easier to move than the other one, and had given no trouble since the change. Having regard to the increasing length of ocean steamers, the entrance lock of the Avonmouth dock seemed short, and at present several American liners could not enter it. In this respect the new Barrow docks had the advantage, for their entrance lock was 900 feet long. One of these long steamers could not turn in the Avonmouth dock, even if vessels were lying only one deep along one quay and the opposite side

were vacant; both sides together would only accommodate six of these liners at the same time with quay berths, so that in this view of the matter the cost per berth of an ocean steamer was in round numbers £54,000, which seemed high.

Mr. MACKENZIE, in reply to Mr. Doherty's communication through the Secretary, observed that he had had a suspicion that the springs were due to filtration from the adjoining river, but his experience at Avonmouth had not confirmed it. He had watched the springs closely when the bottoms were taken out, with the sand exposed and ready for putting the foundation on, and he expected that at the period of high water the volume of water issuing would be considerably increased; but he never could observe that there was any appreciable difference. In some of the principal springs the taste was not particularly brackish.

Whilst dissenting from the opinions of the "value to be derived by discussing such histories of failures," Mr. Stanley had entered into a lengthened and minute discussion of them, and confessed that some of the failures were "striking" and "unheard of" experiences, and, as regarded one of them, desired to know "how this important and interesting work was carried out"? In reply Mr. Mackenzie would refer to these observations in the order in which they occurred in this communication.

The top of the temporary clay dam was at the same level as the sea walls of the adjoining marsh lands. These walls had served the purpose of excluding the Severn tides, no instance of failure being on record. No attempts had been made to drive springs hither and thither. It was sought to collect the weak springs into the outlets provided for the strong ones; the weak springs referred to being, in most instances, weepings in the sand, so numerous that to provide for them separately would have riddled the whole area of the foundations with pipes. Where powerful springs occurred, they were treated in the manner described by Mr. Stanley—except where it was impossible, as under a roller path—or unadvisable, as under the foundations of walls. In these cases horizontal pipes were used to divert the springs to suitable places of outlet. "Where it was found that so thin a layer of clay kept back these springs," the clay had not been removed.

The opinion expressed of cast-iron paddles with brass faces was in contradiction of well known facts. Mr. Harrison, describing a similar arrangement for the sluiceways of the Tyne Docks, remarked, "The sluices at Hartlepool were so constructed by Sir John Rennie, and on examination, a short time ago, they were found to be

as perfect as when first made."[1] Masonry for wood paddles was much more expensive than for iron ones, and the former were more difficult to work by hand power, which, even where hydraulic power was provided, had occasionally to be resorted to.

It would have been better had the masonry under the outer platform been thicker; but he thought the "danger of a blow under the sill" would not be deemed of an alarming character, especially since the water which sprang up beside the piling of the outer invert, and at places in the apron, gradually and entirely ceased, and since no symptoms of movement or disturbance had been observed. When he had referred to a rising of the outer platform of 3 inches, he did not suppose it would be inferred that the whole area of the platform was forced up to that extent. Obviously, such a rising would be greatest about the middle of the platform, and would diminish to nothing at the sides. The platform remained unmoved along the gate recesses and behind the sill, and the 3 inches of rise occurred about the middle of the platform, half-way between the invert and the sill. The greatest extent to which the movement necessitated the lowering of the roller path was $1\frac{1}{2}$ inch, and this at only one point near the centre. The subsequent depression of the platform would therefore give the roller path a slight inclination from the centre towards the ends. The unadjustable roller under the mitre post excited great surprise, and Mr. Stanley appeared never to have heard before of gates being out of plumb. The Author believed the difficulty to be as old as the building of dock gates, and that it happened even with small ones. He knew of three large docks in the Bristol Channel, each of them by different engineers, where the difficulty occurred, and where different measures had been taken to remedy the defect. In one instance the gates overhung 7 inches. They were secured in an upright position while the mitre joint was made, but nothing was done to secure them travelling in that position. He believed there had been no difficulty in working them. The mitres came together at the top first, and then the pressure gradually closes them in their proper positions. In this case the gates had a "flexible nose," but this was nevertheless the usual way of getting over the difficulty. In the case of Avonmouth, the overhang was too great to be overcome in this way, and the "inadjustable" roller was fixed to enable the mitre joint to be properly made and to prevent the gates having a "flexible nose." The contrivance had effected these purposes successfully, and the Author believed it had been

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xviii., p. 495.

the best remedy under the circumstances. It might now be asked whether Mr. Stanley's description of "a shaky gate-recess, a platform that oscillated backwards and forwards as the water was in or out of the lock, and a gate with a flexible nose and an unadjustable wheel under it," was warranted by the facts? The "shaky gate-recess" appeared to be the consequence of a slight settlement which occurred in a mass of masonry 55 feet in height, built upon fine sand foundations from which a large quantity of water was constantly being pumped, and which had never since shown the slightest signs of movement. The "oscillating platform" described the rise of the platform, the greatest extent of which had been 3 inches at one point, caused by a head of 44 feet of water on a temporary dam, and which, after the removal of this dam, subsided to its former level, this one rise and subsidence being the only oscillation that had occurred or was ever likely to occur. The "inadjustable wheel" had quite cured the "flexible nose," and enabled the gates to travel with steadiness. As to the admission of the water making everything safe, the Author preferred his knowledge of the fact to Mr. Stanley's opinion. It was further asserted that no provision had been made at the upper end of the lock for a caisson. This was not the fact, as would be seen by referring to the plan. As to the suitability of wood for the gates, the result of inquiries was, that neither the *teredo navalis* nor any other destructive worm existed in the Bristol Channel. Mr. Stanley thought the gates could not be good ones when made of wood of different densities, and that Memel and light timbers were objectionable on account of their low specific gravity; but "Memel and other light timbers" retained their low specific gravity only a short time in a dock gate almost constantly under water.

The danger of the gates being "torn from the hollow quoin fastenings," as regarded Avonmouth, was an imaginary one. The "deeper gate recesses" had not been found an "obstruction to the quays," and "heavy fenders" (or light ones) were not required at Avonmouth. The gates were well braced without difficulty; and, notwithstanding the "overhanging belly," whatever that was, the gates travelled with ease and steadiness. Mr. Stanley had not stated what he considered was the "old system" of treating dock gates; but the Author could not claim the merit of novelty in the way in which he had treated those at Avonmouth, as Mr. P. W. Barlow[1] had explained the same system many years ago, Mr. Kingsbury applied it to the Victoria dock gates, and many other

[1] *Vide* Transactions Inst. C.E., vol. i., p. 67.

engineers had adopted it. As to "the necessity or economy" of adopting Mr. Hartley's type of gate for "a 70-feet entrance" not being apparent—the "necessity" was that circular sills had been already laid down to suit iron designs when the change to timber gates was decided on; the "economy" that, having to make curved timber gates, the design was adopted which involved the least waste of material. Notwithstanding the dissent expressed from the "rule laid down for fixing the positions of the rollers," it was the one adopted generally in this country for large circular gates. Mr. Hayter, representing a firm who had designed many of the largest curved gates yet built, mentioned that it was the practice of his firm to fix the position of the roller by this rule. It was the position that gave the greatest steadiness in travelling, and the least racking and "working" at the joints, which, in large gates of the Avonmouth type, composed of so many pieces, and with so many joints, was a matter of the greatest importance. On the other hand, for straight gates the usual practice was to place the roller so as to bear about half the weight; and this was doubtless the most suitable position, especially for small gates. Those at Whitehaven were of the straight type, and had about half the head of water to resist that the Avonmouth ones had; the span also was less than at Avonmouth.

Upon such assertions as, that it appeared that nothing was done towards ascertaining "the nature of the strata," and this notwithstanding a reference in the Paper to "trial borings reaching 16 feet under low water of equinoctional spring tides," it was easy to found a charge of want of "ordinary care and foresight." The Author did not know any more careful way of backing a wall than by depositing the stuff in barrowsfull and skipsfull, and spreading, levelling, and punning, as he had described. How "layers of faggots" would have helped matters, when the backing was reduced to nearly a fluid state by saturation from rain after it had been deposited, the Author did not understand. It was stated that the "total cost appeared to have been very heavy," but not a single item was indicated in support of the statement; and the Author must content himself with asserting the contrary, that, considering the nature and extent of the work, the total cost had been moderate. Mr. Stanley having invented a "capital foundation," and other advantages, enumerated a list of failures, of which it need only be remarked that, if every slight settlement in a heavy mass of masonry resting on alluvial foundations was to be set down as a failure, the number of engineers who had built works in such situations without failure must be exceedingly small. Regarding

the "questions for consideration," and the statement that not "a single one of the failures recorded had been remedied" since the dock was completed two years ago, not the slightest symptom had been observed that the remedies described in the Paper had not been completely successful. For the rest, Mr. Stanley seemed to know a good deal after the event, but the Author submitted that the information was not sufficiently ample or correct to sustain the conclusions arrived at.

There appeared to be a misunderstanding with regard to the quantity and price of iron in the dock gates. The 42 tons of iron included—as would be seen by referring to the list under the heading "prices of the work"—"castings, including anchors, gate sluices, two sets of rollers and paths to each leaf, pivots, &c." The first part of the list gave the price of the gates per cubic foot, and stated separately the cost of "straps and bolts," and the above-mentioned castings, &c.; the second part gave the price per square foot of gate; and both the above items had been lumped together as "Ironwork." The cost of wrought iron in one pair of gates was obtained thus: straps and bolts, 9,710 cubic feet at 1*s.* 11½*d.* = £940 13*s.* 2*d.* This amount represented the cost of 42 tons of wrought iron in one pair of outer gates, which gave about £22 8*s.* per ton, instead of £50 as stated by Mr. Stoney. With regard to the economy of timber gates compared with iron, it might be noted, that Mr. Hayter mentioned, as the result of his experience, that iron gates cost on an average £1 15*s.* per square foot of gate, against £1 6*s.* 1⅔*d.*, the cost of the Avonmouth gates given in the Paper. This represented a saving in favour of timber of 8*s.* 10⅓*d.* per square foot, and a total saving on the three pairs of gates at Avonmouth of about £5,366. It should be recollected, too, that the Avonmouth price included two sets of roller paths, &c.

Mr. T. R. Salmond observed, through the Secretary, that Mr. Griffith was slightly in error with regard to the relative cost of the construction of the Queen's quay as compared with the Albert quay, since the amount paid to the contractor for the latter work was £41,601 18*s.* 4*d.*, whilst that paid for the Queen's quay works was £57,358 15*s.* 6*d.* When comparing the cost of works contracted for in 1872 and those contracted for in 1875, it should be remembered that in the former year the prices of labour and material varied from 15 to 25 per cent. less than in the latter year; and further, it should be borne in mind that the Queen's quay works were considerably greater than those of the Albert quay, as about 4 acres of the old quays, from coping to low-water mark, had to be

removed and conveyed to a distance, for the purpose of making up reclaimed lands. The approximate estimate of £50,000, given by him when the Albert quay was in course of construction, included the cost of all collateral works over and above the contract amount, such as sewers, drains, gas and water-piping, lines of tramway, square sets and boulder paving, &c. The objections to the construction of a permanent stone structure along the Queen's quay were, first, the prime cost, which would be considerable compared with that of a timber wharf; and secondly, that the requirements of the port and harbour of Belfast for the next century could not be anticipated, as the depth of water now provided for might not within the next fifty years be adequate for the requirements of a class of vessels which might traffic to this port. On the point of economy, obviously if the cost of a timber structure was £58,000, and of a permanent stone structure £68,000, the difference was £10,000. Assuming, then, that the timber structure, the greater portions of the exposed parts of which were creosoted, should have an existence of forty years (the old quay which it replaced, though not creosoted, lasted thirty years), the value of the sum of £10,000, at 5 per cent. compound interest, would amount to £70,040, which sum, even allowing for the probable increase in the cost of labour and material, would, at the expiration of the term of existence assumed for the wharf, be sufficient to re-construct it; or if at that time it was determined to erect a stone or concrete wall, the same sum of money would be in hand for that purpose, independently of which the sheeting piles, driven in connection with the timber structure, could be utilised for the facing of the substructure of the concrete work, the cost of which timber facework amounted originally to upwards of £14,700.

In reply to Mr. Hayter's observations relative to the various methods suggested by Sir John Hawkshaw for securing the walls of the Dufferin and Spencer docks, he might state that the settlements in the walls referred to had for the most part subsided prior to his appointment to the engineership of the Belfast harbour, in the year 1871. The Spencer dock entrance wall was the only exception. This wall collapsed in the most sudden and startling manner, for, though carefully watched, the indications of settlement were no greater in this part of the work than in others where the walls were at present standing, to all appearance, firm and stable; and even up to within an hour before the final giving way of the wall, workmen were engaged in the removal of the heavy, and the substitution of light, material for "backing." The men had only left the work a very short time

when the wall collapsed—a fortunate occurrence, as, had it given way whilst the men were at work, great loss of life would probably have attended the disaster.

Mr. J. EVELYN WILLIAMS, in reply to Mr. Stanley's communication through the Secretary, observed that a sill with radiating joints on plan, and curved in elevation, was a very costly piece of work, owing to the additional waste of material and extra labour in working and setting. Further, it sometimes happened that a vessel's fender, or other matter, got jammed between the gate and the face of the sill. It was obvious that mischief of this nature would be less likely to happen with a flat sill, where the area of meeting surface was a minimum, and constant throughout. To avoid danger arising from the hydrostatic pressure of the head of water in the dock, it would be noticed that the thickness of concrete under the sill was in excess of that under the invert. With reference to the use of pitch pine for the ribs and planking of the gates, it was found that locally, with the exception of greenheart, pitch pine yielded less rapidly than other wood to the ravages of the worm. The timber was not creosoted, but received three coats of Stockholm tar.

Mr. GEORGE FOSBERY LYSTER states, in a letter to the Secretary, that the dock referred to by Mr. Doherty was never abandoned as a graving dock; and that, since his report for the year ending 24th June, 1867, no difficulty has been experienced in connection with the "springs," while the dock has been in constant use.

---

November 19, 1878.

JAMES ABERNETHY, Vice-President,
in the Chair.

November 26, 1878.

JOHN FREDERIC BATEMAN, F.R.SS. L. & E., President,
in the Chair.

The discussion upon the preceding Papers, on the Avonmouth Dock, Belfast Harbour, and the Whitehaven Harbour and Dock Works, occupied these meetings.

---

December 2, 1878.

# SPECIAL GENERAL MEETING.

---

J. FREDERIC BATEMAN, F.R.SS. L. & E., President, in the Chair.

The SECRETARY read the Summons convening the Meeting as follows:

"The Institution of Civil Engineers.

"25, GREAT GEORGE STREET, WESTMINSTER, S.W.
"22*nd November*, 1878.

"The COUNCIL consider it expedient to propose the enactment of certain new Bye-Laws and Regulations, and the alteration and repeal of certain existing Bye-Laws and Regulations. A printed draft, showing such proposed enactments, repeals, and alterations, is sent herewith.

"A General Meeting will be held at the house of the Institution on Monday, the Second of December, 1878, at 2.30 o'clock in the afternoon, to decide on the same.

"At this Meeting all existing Members, Associates, and Honorary Members will be entitled to be present, to take part in the proceedings, and to vote.

"By Order,
"JAMES FORREST,
"*Secretary.*"

The PRESIDENT then proposed that the Bye-Laws, of which a copy had been sent to all the Corporate Members in the United Kingdom, should be approved and adopted.

Mr. W. H. BARLOW, Vice-President, seconded the motion.

Upon which Mr. LONGRIDGE, Member, explained the reasons for certain amendments in the proposed Bye-Laws which he intended

to submit, and concluded by moving the following amendment as to Section II.:

> "That in the opinion of this meeting, all 'Associates' now on the Register who are Engineers by profession, and who possess the qualification as defined in the Bye-Laws, should be forthwith transferred to the class of Members; and that the remainder of such Associates, Engineers by profession, should, if they desire it, be also transferred to the class of Members so soon as they shall be duly qualified.
>
> "That all 'Associates' now on the Register who are not Engineers by profession, shall retain the title of 'Associate,' and shall have equal corporate rights with the Members.
>
> "That future 'Members' shall be persons possessing the qualification as defined by the Bye-Laws, and who shall have been elected in the usual manner.
>
> "That future Associates shall be persons not Engineers by profession, but who are qualified to concur with Civil Engineers in the advancement of professional knowledge; but such persons shall not have corporate rights as members of the Institution.
>
> "That all Students, present and future, shall remain Students until qualified to be transferred into the class of Members."

This was seconded by Mr. JOHN DIXON, Associate.

It was then agreed that any gentlemen who had particular Amendments in view, should state the substance of their opinions, in order that the members generally might have an opportunity of considering the whole subject. Whereupon, Mr. R. PRICE WILLIAMS, Member, and Mr. J. N. DOUGLASS, Member, advocated that the Engineering Associates should be styled "Junior Members;" and Mr. W. B. LEWIS, Member, and Mr. W. PARKES, Member, expressed the intention to propose and second respectively, at the proper time, an Amendment giving the designation of "Assoc. M. Inst. C.E." to "Associates being Corporate Members."

After discussion, the PRESIDENT intimated that, having regard to all the circumstances, and the evident feeling of the general body, the Council had no objection to offer to Mr. LEWIS's proposition.

Whereupon Mr. PRICE WILLIAMS and Mr. LONGRIDGE withdrew

their suggestions, when it was moved by Mr. LEWIS, seconded by Mr. PARKES, and

> "*Resolved*,—That in paragraph 9 of Section II., after the words 'any Member' be inserted 'Associate being a Corporate Member;' and after the words 'abbreviated forms, viz., M. Inst. C.E.,' be inserted 'Assoc. M. Inst. C.E.'"

Mr. TOPHAM, Associate, moved, and Mr. DAVID THOMSON, Member, seconded the following amendment:

> "That in Section XV., clause 4, the hour '9' should be substituted for '5½' P.M."

This, upon being put from the Chair, was declared to be lost.

The PRESIDENT then proposed, and Mr. ABERNETHY, Vice-President, seconded, the following Resolution:

> "That the Bye-Laws as now presented to the meeting be adopted, subject to Mr. LEWIS's amendment, it being understood that his amendment applies to all present and future Engineering Associates, and to no others."

Upon which the following amendment was proposed by Mr. LONGRIDGE, Member, and seconded by Mr. DIXON, Associate:

> "That in Article 2, Section V., the words after 'the ensuing year' to the end of the paragraph be omitted, and in lieu thereof the following words substituted: 'The list shall contain the names of all such persons (Corporate Members) as shall be nominated by the Council, and of all such other persons (Corporate Members) as shall have been nominated in writing, signed by at least ten Corporate Members, and delivered to the Secretary fourteen days previous to the election; and in this list all the names shall be printed in alphabetical order and in the same character of type."

This amendment having been put, was negatived by a large majority, when the Resolution proposed by the President was put and carried.

The proceedings then terminated by a vote of thanks to the President.

(Signed) J. FREDERIC BATEMAN.

December 3, 1878.

JAMES ABERNETHY, Vice-President,
in the Chair.

The following Candidates were balloted for and duly elected:

WILLIAM BAXTER, LESLIE CLARK, GRANVILLE CARLYLE CUNNINGHAM, GEORGE EDWARD GRAY, JACOB HIGSON, JOHN HIGSON, ALEXANDER MACNAB, ALFRED PENNY, Jun., JOHN RALPH REES, WILLIAM RUSS, WILLIAM HENRY STUBBS, and JOHN SWINBURN, as Members.

It was announced that the Council, acting under the provisions of Sect. III., Cl. 8 of the Bye-Laws, had transferred HENRY BANCROFT, EDMUND SCOTT BARBER, HENRY PURDON BELL, JOSEPH BRADY, JOHN WILLIAM JOHNSON, EDWARD HENRY KEATING, CHARLES BENJAMIN KNORPP, ROBERT REYNOLDS, and LIONEL HENRY SHIRLEY, from the class of Associate to that of Member.

Also that, under the provisions of Sect. IV. of the Bye-Laws, the following Candidates, having been duly recommended, had been admitted as Students of the Institution:—JOSEPH ARMSTRONG, FRANK WILLIAM BELFIELD, VALENTINE JOHN STUART BLOMFIELD, WALTER LONGLEY BOURKE, ALEXANDER BREMNER, NORRIS BRETHERTON, FRANK CHAUNTLER, WILLIAM HENRY WALTER COLEY, WILLIAM HENRY EDINGER, ARTHUR SCUDAMORE EMERY, HANS DITLER FABRICIUS, GEORGE SEPTIMUS FIRTH, ROBERT VINCENT GLOVER, LLOYD HASSELL, EDWARD BERESFORD HEARNE, WILLIAM FIELD HOW, REGINALD GRANT JACKSON, GEORGE KAY, JOHN LATIMER, WILLIAM MACLEOD MACKINNON, RAYNES LAUDER MACLAREN, CHARLES PERCIVAL METCALFE, ALBERT MOODY, SAMUEL HALL PARKER, HENRY ATWELL PURDON, GEORGE WILLIAM DENNISTOUN SCOTT, WALTER SHELLSHEAR, WILLIAM DICKSON SKRINE, FREDERICK WILFRID SCOTT STOKES, WILLIAM THORBURN, FRANCIS DAVID TOPHAM, EDWARD HENRY TOULMIN, HERBERT TULK, RICHARD WADDINGTON, and ALFRED RALPH WATSON.

No. 1,465.—"On the Heating and Ventilating Apparatus of the Glasgow University." By WILSON WEATHERLEY PHIPSON, M. Inst. C.E.[1]

GENERAL MORIN, in his well-known "Études sur la Ventilation," has insisted upon a fact that appears to have escaped numerous

[1] The discussion upon this Paper occupied portions of two evenings.

observers. In spite of the lightness of the atmosphere, like all other bodies it obeys the laws of gravitation, and is subject to those laws of inertia in virtue of which no body can change its state of repose or motion except by obeying the forces which act upon it. These elementary principles are frequently lost sight of by persons who occupy themselves with the ventilation of buildings.

It is not uncommon, indeed, to hear announced, as incontestable axioms, that "Air has a tendency to rise;" that "Cold air cannot rise;" that "Warm air cannot fall;" that "Air must not be conducted horizontally;" all of which are errors of judgment based upon false notions, and lead to uncertainty and confusion. In reality, air tends neither to rise nor to fall; it merely obeys the action of the forces by which it is solicited. Thus, in certain places, where warmer than the adjacent air, it rises, and gives place to the heavier cooler air. In this manner the flame of a candle or lamp, or a stove, incites motion in the air adjacent, causes it to rise, and the cold air around to flow towards the heated object. Thus, again, the air in contact with cold walls or windows becomes heavier than that around it and falls, while the latter moves to its place. Now, if slight variations of temperature produce such effects as these, slight variations of pressure or suction will produce similar results.

In the year 1864, when the building of the new University of Glasgow was determined upon, a sub-committee of the professors, amongst whom were Sir William Thomson, Dr. Allen Thomson, Professor H. Blackburn, and the late Dr. W. J. M. Rankine, considered the general principles which should form the basis of the operation to secure for the new building the most efficient system of ventilation and warming. After a lengthened investigation they came to the following conclusions:

1. That the foul air should be removed through outlets as near as possible to the place where it is produced, *e.g.* passages under desks or seats.

2. That the total area of the orifices of such outlets should be about $\frac{1}{5}$ square foot per sitting, or 28 square inches.

3. That the total area of the orifices of the inlets for fresh air should be about double the area of those of the outlets for foul air, or $\frac{2}{5}$ square foot per sitting.

4. That the inlets for fresh air should be at a high level and distributed round the circumference of the rooms.

5. That fresh air should be supplied both hot and cold, and each class-room be provided with means for mixing it.

6. That the total supply of air to the class-rooms should be $\frac{6}{10}$ cubic foot per sitting per second.

7. That the sectional area of the channels or conduits for carrying away foul air should be $\frac{1}{20}$ square foot per sitting.

8. That the final outlets of the foul air should be so placed that none of it should return to the building.

9. That the fresh air should be drawn from some place where the air is always pure.

10. That the fresh air should be forced in by one or any required number of suitable machines.

11. That the foul-air conduits should lead to chimneys in suitable positions, provided with furnaces capable of being lighted, the area of the furnace grate being $\frac{15}{1000}$ square foot per sitting.

12. That the hot part of the fresh air should be heated by hot-water tubes, and that the most efficient position for such tubes was in the vertical passages in which the current of air ascends.

These resolutions were forwarded to the late Sir George Gilbert Scott, R.A., the architect, who selected three engineers to submit to the Committee suggestions in a practical form. The plans adopted by the Committee (Plate 6) represent the work carried out under the Author's directions.

In working out these suggestions, it was found that the allowance of $\frac{6}{10}$ cubic foot of fresh air per second per sitting for class-rooms, if the class was only of one hour's duration, was too much, and that the vertical air shafts necessary to supply this large volume of air assumed such proportions that the walls would not admit of their construction. According to well-known authorities, a supply and extraction of 700 cubic feet of air per hour per sitting is ample in this case. The Author, therefore, based the calculations of the sizes of all air passages, &c., for both the outlet and the inlet of the air, on a supply equal to six times the cubical space of the class-rooms in the hour as a minimum, or about 750 cubic feet per hour per sitting; thus bringing up the total volume of air to be passed through the apparatus per hour to 1,800,000 cubic feet.

The different velocities per second which this volume of air should travel at different parts of the apparatus, to ensure the amount required at the several points with a given area of channel, form the most important item in all plans for ventilation and warming, as regards simplicity of construction, minimum resistance to the flow of air, and cost of the application. No general rule can be laid down with a view of fixing these

velocities, as they depend entirely upon the size, situation, and requirements of each building.

As a guide, however, General Morin gives the following velocities:

| | Feet. | Feet. | |
|---|---|---|---|
| For main inlets or outlets . . . . . | 5·9 to | 6·6 | per second. |
| „ 1st series of channels . . . . . | 4·3 „ | 4·6 | „ „ |
| „ 2nd „ „ . . . . . | 3·3 „ | 3·9 | „ „ |
| „ final inlets or outlets . . . . . | 2·3 „ | 2·9 | „ „ |

Considering the number of experiments and reliable observations made by General Morin on the different systems of ventilation and warming in actual operation, these will be found of great help in determining the area of the channels for any apparatus, but more especially so when exhaustion of the air alone is adopted.

The Author believes that these velocities are too low to produce a practical and economical application, in any extensive system of ventilation and warming. For this reason, in computing the different velocities for the building under notice, he fixed as a basis for calculation that the air should travel through the apparatus as follows:

| | Feet per Second. |
|---|---|
| 1. Fan . . . . . | 12 |
| 2. Distributing channels from fan to air-chambers . . . . | 6 |
| 3. Distributing channels from warm air-chambers to vertical flues . . . . . | 5 |
| 4. Remaining parts or vertical flues to rooms . . . . . | 4 |

The velocities for the vitiated air channels and flues were calculated in a similar manner, assuming the ascending velocity in each extracting shaft to be 7 feet per second. The different velocities of the air in motion having been fixed, the requisite size of any flue or channel was obtained by dividing the volume of air supplied per second by the velocity per second. This will be found in practice sufficiently accurate. Thus, for a supply of 750 cubic feet of air per hour per sitting, or $\frac{1}{5}$ cubic foot per second per sitting, the area of the inlets from the apparatus to the class-rooms, calculated at the velocities above-named, should be $\frac{1}{18}$ square foot per sitting, or 8 square inches; and the area of the exit $\frac{1}{20}$ square foot, or 7 square inches per sitting. For a class-room of two hundred sittings, to receive a supply of 150,000 cubic feet of fresh air in the hour, 11 square feet of opening would be required for inlet, and $9\frac{3}{4}$ square feet for outlet. Although this difference in the area of inlet to that of the area of escape works

well in practice, authorities do not all agree; and whilst some would rather that the area of outlet should be larger than the area of inlet, on account of increase of volume in the vitiated air, Professor Pettenkofer states, from a series of experiments on the ventilation of different buildings, that, provided ample provision is made for the inlet of fresh air, the vitiated air will find its way out of any ordinary occupied space. The Author is of opinion that these remarks apply more to small rooms or private apartments, where but few sources of vitiation of the air exist, and that in such cases Professor Pettenkofer's views may be correct. However, the disposition of the inlets and outlets of the air for ventilating and warming any given space evidently forms an important matter for consideration. For the building under notice it was determined by the Committee of Professors, but this by no means decides the question for all kinds of buildings.

Experience obtained in different classes of buildings, where various positions of inlets and outlets have been adopted, shows that the best solution of this problem consists in having all inlets of fresh air, either warm or cold, at a mid-level of the space to be ventilated; and that the extraction of the vitiated air should be both from a high and a low level simultaneously. The mid-level disposition is more effective than the higher level distribution, besides being of more economical construction; it has great advantage over the low-level distribution in being capable of delivering the air in larger volumes, and at higher velocities, without fear of draughts being felt. Where the height of the space to be warmed is very great, as in the Royal Albert Hall of Arts and Sciences, South Kensington, a mid-level distribution would not have been so effective; the air is therefore distributed at different levels, to lessen the cooling influence whilst in motion over so great a vertical space.

In considering the best form of channel, or air passage, it should be borne in mind that the resistance to the air in motion increases as the square of the velocity of the current, and is directly proportional to the perimeter of the channel, and inversely as the area of the transverse section perpendicular to the axis of the current. As stated by Mr. Hawksley, Past President, Inst. C.E.,[1] it follows essentially the law which regulates the flow of inelastic fluids through tubes. The circular or oval form of channel would suggest itself as the best shape to reduce to a minimum this resistance to

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxiii., p. 53.

the flow of the air. But, as passages of this form entail more labour and expense in their construction than any other, the Author, in many of his applications, has been led to adopt channels having their height nearly equal to their width, with straight sides of an even or smooth surface, flat bottoms, and semi-circular or segmental arches for covering. In the particular application which forms the subject of this Paper, the covering of the channels from all the air chambers is formed of plates of corrugated iron with a layer of about 6 inches of concrete over them; but the channels from the fan to the different air chambers have semi-circular arches formed in two 4½-inch rings of brickwork.

When constructing the flues in the thickness of the walls, the Author prefers that all the joints be struck fair, and the flues lime-whited, as the resistance to the flow of the air is thus more reduced than if the flues are pargeted in the usual way. For the channels in the roofs for conveying away the vitiated air, sheet-iron, zinc, lath and plaster, or matched boarding, lined outside with canvas, and painted, are often adopted. The question of economy frequently decides the materials to be used in the construction of the air passages; but in no case should the desirability of a smooth surface—with as few sharp angles, sudden enlargements or contractions, as possible—be overlooked.

The details concerning the levels, the directions of the air channels, and the position of the vertical shafts, should be accurately laid down on the architect's working drawings previous to the works being commenced.

As to the shape of the fan for supplying 1,800,000 cubic feet of air in the hour, the Author was governed to a great extent by the successful employment of similar fans previously in buildings ventilated under his direction. His reason for adhering to the form hereafter described is, that whilst screw fans are of no more complicated form of construction than the ordinary rotary fans, they are less liable to get out of order. They appear also, when moving at low pressure, to afford the same effective power, provided the minimum of resistance is given to the inlet and outlet of the air, and the delivery passages are of large dimensions.

The force necessary to propel air through any passage being equal to the square of the velocity into the total surface multiplied by the coefficient of friction, pressure of the air being uniform, and admitting the coefficient of friction in air passages as given by

Mr. Hawksley at 0·03, Mr. D. P. Morrison submits, as a practical formula for ventilation, the following expression[1]:

$$H = \frac{K V^2 P L}{A}.$$

H = the head of pressure, in feet of air of the same density as the flowing air.
L = the length of the pipe or passage in feet.
P = the perimeter of the cross section in feet.
A = the area of the pipe or passage in square feet.
V = the velocity in thousands of feet per minute.
K = the coefficient of friction taken at 0·03.

Taking D as the diameter for circular passages whose diameter is small in proportion to their length,

$$H = K V^2 \times \frac{4 L}{D},$$

and for irregular-shaped channels,

$$H = K V^2 \times \frac{P L + 200 A}{A}.$$

When this formula is applied for the calculation of the head of pressure, H, in an apparatus for heating and ventilating where the velocities and the area of channels have various proportions, it is found necessary to take a mean area, a mean perimeter, and a mean velocity for the whole length of the channels, without which too high a head of pressure would be given. Applying it, therefore, for the requirements in question, and assuming that—

V = the mean velocity through the channels = 6·75 feet per second, or 0·400 in thousands feet per minute.
A = the mean area in square feet = 26·83
P = the mean perimeter in square feet = 19·63
L = the length of air passage in feet = 810
K = the coefficient = 0·03

$$H = \frac{0{\cdot}03 \times 0{\cdot}400^2 \times 19{\cdot}63 \times 810}{26{\cdot}83} = 2{\cdot}85,$$

2·85 feet of air = 0·04 inch of water.

Taking into consideration the friction of the air through the channels, 1 inch or 5·2 lbs. of water on the square foot, would nearly represent the total head of pressure; and thus a volume

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliv., p. 27.

)0 cubic feet of air moved per minute with this head of
) represents an effective HP. of

$$\frac{30{,}000 \times 5{\cdot}2 \text{ lbs.}}{33{,}000} = 4{\cdot}54.$$

ch a low pressure the effective power of the fan does no
)0 per cent. of the indicated HP. of the engine, so that about
ill be required for moving the air.

method of calculating the power necessary to drive the air
passages bears a fair comparison with Table No. III. on
r Public Buildings[1] by Mr. Briggs. He gives, for a fan
a diameter, making from 140 to 280 revolutions per minute,
ivering from 20,000 to 40,000 cubic feet of air per minute,
½ HP. For the Glasgow University, the Author adopted
owing method: Taking the velocity of the air at 12 feet
nd, the diameter of fan to supply a volume of air equal to
)0 cubic feet per hour, or 30,000 cubic feet per minute, will
6 inches. The amount of air put in motion per second
hus be 500 cubic feet, and the weight of air to be lifted
ute

$$= \frac{500 \times 60}{13} = 2{,}308 \text{ lbs.}$$

ree revolutions per second the velocity of the fan would
et, and the height traversed by a gravitating body to
this velocity per second is equal to 77 feet, then

$$\frac{2{,}308 \times 77}{33{,}000} = 5{\cdot}38 \text{ HP.}$$

nt in actual practice to from 8 to 9 HP.

olume of air evacuated by an extraction shaft increases in
atio to its area, and proportionately with the square root
eight, and the square root of the difference of the external
rnal temperatures. It is found, experimentally, that, the
temperature of a shaft remaining the same, an increased
s very little influence on the velocity of the up-current,
an increased resistance is given by the additional surface
to the air in motion. Also that, for an economical con-
n, when large volumes of air are to be exhausted, it is
increase the area than to raise the temperature of the shaft.
, however, be borne in mind, that to ensure a steady up-
of from 4 to 8 feet per second, a difference of temperature

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxx., p. 295.

of 30° to 40° Fahrenheit must be maintained in the shaft, and tha the termination of discharging openings should be well protecte against the action of the wind. These remarks are applicable o the assumption that a uniform temperature is maintained in th whole height, and that no allowance need be made for any differenc of temperature between the bottom and the top of the shaft.

Péclet's formula, $U = 8{\cdot}85 \sqrt{\frac{a\,D\,H\,(t-T)}{L+4\,D}}$ in which $a$ = a efficient of friction, for the calculation of the velocities of the curren in chimneys, having been found to lead to too high a resul several engineers have endeavoured to bring it to a more practica shape, and to make it coincide with experiments and direct obser vations. As the results of a series of measurements, the followin formula has been prepared for calculating the velocity in an extracting shaft:

$$U = \sqrt{\frac{D\,H\,(t-T)}{L+16\,D}}.$$

U = the velocity per second.
D = the diameter of the shaft.
H = the height of the shaft.
T = the external temperature.
$t$ = the internal temperature of the shaft.
L = the length of the evacuation channels.

General Morin remarks that this formula is nearly identical with the one he obtained by theoretical calculations, assuming the coefficient of resistance to be 0·01. The Author, when computing the proportion of the channels and extraction shafts in the apparatus to be described, used this formula, assuming the differ ence of temperature between the shafts and the external air to b from 20° to 25° Fahrenheit.

In determining the heating surface of an apparatus, consideratio should be given to the climate of the place, the position and su soil of the building, the materials and thickness of the walls, an the area and construction of the windows. When the subsoil is clay, and the heating surface is placed in channels or chambe level with the foundations, great care should be taken to ensu that the drainage of the building is sufficiently deep to clear a water from these channels, or much loss of heating power will b caused by the evaporation of the surface water which collects i different parts of the apparatus.

The calculation of the heating surface to be fixed in a warmin

chamber, when the air to be heated is put in motion by mechanical means, is much more complicated than that necessary for the power required when the heating surface is fixed in the space to be warmed.

In the apparatus about to be described, or in any other on a similar principle, allowance above the actual volume of air to be warmed must be made for the increased velocity of the air in motion, for the loss of heat from the distance traversed by the air to the space to be warmed, and for the loss of heat from the heating-surface being below ground and in chambers.

The Author has worked out several formulæ, and finds one which meets his requirements, and which has been used in proportioning the present apparatus, in which

$$L = \frac{(P - t) \times (T - t)}{P - T} \times 0{\cdot}0045\,C.$$

L = the length of 4-inch hot-water pipe fixed in the chamber.
P = the temperature of the 4-inch hot-water pipes taken at 180° Fahrenheit.
T = the temperature to be maintained in the class-rooms, 57°.
$t$ = the temperature of the external air taken at 20° Fahrenheit.
C = the volume of air to be warmed per minute.
0·0045 = the coefficient for 4-inch hot-water pipes.

The volume C of air in the building under consideration is obtained by multiplying the cubic space of the class-rooms to be warmed per minute by the velocity of the air in motion in the chambers, taken at 3 feet per second. The value of C for the different chambers is:

| | Cubic Feet. |
|---|---|
| In the south-west chambers . . . . . | 12,300 |
| „ south-east „ . . . . . | 10,500 |
| „ east „ . . . . . | 15,800 |

To the quantity of 4-inch hot-water piping calculated, about one-third more was added, on account of the pipes being placed below ground. Thus the proportional heating surface fixed in each chamber was as follows:

| | Feet. |
|---|---|
| In the south-west chambers . . . . . | 3,500 |
| „ south-east „ . . . . . | 3,000 |
| „ east „ . . . . . | 4,500 |

Besides this amount of heating surface, 4-inch flow and return pipes were fixed in all channels conveying warm air over a distance of more than 60 feet from the main source of heat.

According to General Morin, 12 square feet of heating surface are required for every 1,000 cubic feet of space to be warmed, when the pipes are in chambers; and for efficient work, the warm air must not be conveyed horizontally more than 60 to 70 feet. Monsieur Grouville allows from 4 to 5 feet of heating surface per 1,000 cubic feet of space, when the pipes are in the rooms to be warmed, this allowance being calculated on the assumption that the temperature of the pipes is 176° to 194°. Mr. Anderson, in his valuable experiments on the heating power of hot-water pipes,[1] estimates that about 15 square feet of heating surface are necessary for every 1,000 cubic feet of air to be warmed when the pipes are concealed, assuming their temperature to be about 160°. Mr. Hood deduced from numerous experiments that from 5 to 12 square feet of heating surface are necessary per 1,000 cubic feet, according to the requirements of the building; but that, when the pipes are in trenches, an additional 5 to 7 per cent. must be allowed to make up for the heat lost by this arrangement. From experiments by Tredgold, water contained in an iron pipe of 4 inches diameter internally, and 4½ inches externally, loses 0°·851 Fahrenheit of heat per minute, when the excess of its temperature is 125° above that of the surrounding air. From these data Mr. Hood estimates that 1 foot in length of 4-inch pipe will heat 222 cubic feet of air, 1° per minute. According to Mr. D. K. Clark, however, this estimate is too low, as it is based on too high a value for the specific heat of air, 0·2767. If the quantity be increased in the inverse ratio assumed, and with the actual specific heat of air, the volume of air raised 1° by 1 foot in length of 4-inch pipe, when the excess of temperature is 126° Fahrenheit, will be—

$$222 \times \frac{0{\cdot}2767}{0{\cdot}2377} = 258 \text{ cubic feet.}$$

The proportional heating surface adopted by the Author bears a fair comparison with the usual practice. It maintains the different air chambers at the temperature of 100°, even in severe weather.

The selection of the proper form of boiler for an extended apparatus of this kind is of great importance, as upon it depends the efficient and economical working of any application. Mr. Hood remarks, in his 'Treatise on Warming Buildings,' &c.,[2] that "it is no recommendation of a boiler" "to say that it contains a certain number of square feet of heating surface in a given

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlviii., p. 257.
[2] Page 81.

space; for unless this surface can be acted upon by the radiant heat of the furnace, a boiler of less than one-half the superficial measurement, if judiciously contrived for this object, may greatly exceed it in power." The conditions of a good hot-water boiler are "that it shall expose the largest surface to the fire in the smallest space; that it shall allow free circulation of the water through its entire extent;" and that it shall be of simple form in its construction. No boiler, in the Author's opinion, meets these requirements in a more economical manner than the Cornish type, when the power of the apparatus exceeds 2,000 superficial feet of heating surface. In this application Cornish boilers have been adopted, their size having been determined by assuming 35 superficial feet of pipe to 1 square foot of effective boiler-heating surface. The whole of the internal flue has been calculated as effective, and the side flues as one-half effective, heating surface.

In an apparatus for heating the air artificially, its hygrometrical state should be considered, and means adopted, when found necessary, to restore the air to its proper degree of moisture before leaving the heating chamber. Surgeon-Major de Chaumont, M.D., in a Paper read before the Royal Society,[1] gives the following data as the standard of good air for ventilation: Temperature of dry bulb 63° to 65° Fahrenheit, of wet bulb, 58° to 61°; in any case the difference between the two thermometers (wet and dry bulbs) should not be less than 4°, nor exceed 5°, the temperature never being much below 60°. Vapour should not exceed 4·7 grains per cubic foot at a temperature of 63°, or 5 grains at a heat of 65°. Humidity should not exceed 73 to 75 per cent.. Carbonic acid (respiratory impurity) should not exceed 0·0002 per cubic foot, or 0·2000 per 1,000 volumes. Taking the mean external air ratio at 0·4000 per 1,000, this would give a mean internal air ratio of 0·6000 per 1,000 volumes. Of the several arrangements for moistening the air, the best are those that present a large and shallow evaporating surface. When the air in circulation is heated by hot water apparatus at low pressure, and when its temperature is not above 100°, little difficulty is experienced in maintaining the proper interval between the wet and dry bulb thermometers in any warming chamber, or to ensure to the incoming air its proper degree of moisture.

The apparatus consists of a fan, 7 feet 6 inches in diameter, worked by an 8-HP. steam engine, fixed near the main tower of

[1] *Vide* Proceedings of the Royal Society, vol. xxiii., p. 199.

the building. The fan draws its supply of air from four shafts, 5 feet deep by 3 feet wide, formed in the wall of the tower, terminating in a chamber, into which the external air is admitted. By this means a supply of fresh and pure air is obtained from a height of 100 feet, far from all local causes of contamination. The fan then forces the air through a series of subterranean passages leading into five distinct air chambers. (Plate 6, Fig. 1.)

The south-west and south-east chambers are under the gateways leading to the quadrangles; the east chamber is in a sub-basement in the centre of the east wing; and the north-west and north-east chambers are constructed in each side of the main walls of the libraries and museums. In these chambers the fresh air is warmed previous to its distribution, by being passed over the surface of 4-inch hot-water pipes, arranged in coils, each chamber having its distinct hot-water boiler. The heating powers obtained in these chambers vary according to the amount of work they have to do. The combined heating surface throughout the building is equal to about 21,000 feet of 4-inch pipe, and the average temperature these chambers are maintained at is 100° Fahrenheit.

The air, having been sufficiently heated in the chambers, is then conveyed by branch channels to a series of vertical air shafts formed in the thickness of the walls, having their lower openings in the horizontal channels, and their upper apertures in the class-rooms. These shafts are 18 inches broad by 12 inches deep for the ground floor, and 12 inches square for the upper floors. The fresh air is admitted in all the class-rooms, with few exceptions, near the ceiling; but in the libraries and museum, which have distinct apparatus, the air enters at the level of the skirting. In some of the class-rooms used in the morning, in addition to the openings at a high level two extra openings are provided at the level of the skirting. The area of inlet to each class-room is equal to $\frac{1}{18}$ square foot per sitting; and this delivers, at a moderate velocity, a supply of air equal to 750 cubic feet per hour per sitting. Valves of simple construction are fixed to each inlet-opening, and are regulated by the attendants.

For the extraction of the vitiated air from the class-rooms, three shafts have been provided at the south-west, south-east, and east angle towers, the size of each being 5 feet broad by 3 feet wide, and about 96 feet high. The extracting power of the shafts is increased by the waste heat from the hot water and steam boilers being carried inside them by a cast-iron flue or pipe, 2 feet 3 inches in diameter, thus maintaining a temperature of 25°, as a minimum,

above the external air. The extraction shafts communicate with the different class-rooms by a secondary system of horizontal and vertical channels. The sizes of these channels and their branches are calculated on the allowance of $\frac{1}{20}$ square foot per sitting, and their respective sizes are graduated according to their distance from the main shafts. The exit of the air from the class-rooms is through perforations in the risers of the seats, as shown in Plate 6, Fig. 2; but, in the medical and other class-rooms, which are used in early morning when much gas-light is required, openings for exit have been provided near the ceiling, in addition to these perforations. In the libraries and museum buildings no mechanical extraction of the vitiated air is adopted; but ordinary air flues are carried up in the walls, with discharging openings to the external air over the roofs. In the anatomical department, in which there is a special warming apparatus, after various schemes had been proposed the only system of ventilation adopted was the open windows at a high level around the room. For the chemical laboratory an exhaustion shaft is provided for the removal of noxious vapours.

Cornish boilers, 10 feet long by 4 feet wide, with 2-feet 6-inch tubes, are used for circulating the water in the hot-water pipes in the different chambers, and are all set on the wheel draught, with every facility for cleaning out the flues. The steam boilers, of which there are two, one being supernumerary, are 10 feet long by 4 feet 6 inches wide, with 2-feet 4-inch tubes, set in the same way. They are made of the best Glasgow iron, $\frac{3}{8}$ inch thick, with Lowmoor iron over the furnaces.

The fan, to propel the air through the passages, is on the principle of the Archimedean screw, having four blades set at angles of 60°, on a spindle parallel to the axis of the air channel. The blades are slightly twisted, to present in rotation an uniform resistance to the air in motion. The shaft of the fan is $2\frac{1}{2}$ inches in diameter; it runs between two pillar blocks carried on two cast-iron girders, fixed across the centre of the chamber. The fan is driven direct off the fly-wheel of one of James Robertson's valveless steam engines, having a vertical cylinder $8\frac{1}{2}$ inches in diameter and a 12-inch stroke, the whole forming a compact piece of machinery.

The 4-inch pipes fixed in the different chambers are ordinary hot-water pipes, weighing about 100 lbs. to the 9-feet length. They were all proved to 200-feet water-pressure before delivery. They are generally arranged in upright coils extending the whole length and width of the chambers, thus presenting to the incoming air a

large exposed heating surface. In the north-west and north-east apparatus, for the museums and libraries, the pipes are arranged in four chambers as continuous coils, running the whole length of the main walls.

The extent of heating surface exposed in each chamber is—

| | Square Feet. |
|---|---|
| In the south-west chamber . . . . . | 3,500 |
| „ south-east „ . . . . . | 3,000 |
| „ east „ . . . . . | 4,500 |
| „ north-west „ . . . . . | 4,500 |
| „ north-east „ . . . . . | 4,000 |
| „ anatomical department . . . . . | 645 |
| „ chemical „ . . . . . | 565 |
| | 20,710 |

In the Appendix will be found a register of the average monthly temperatures of the class-rooms, recorded by the engineer at 8 A.M. It will be seen that, whatever may be the external temperature, the rooms are maintained uniformly at about 54°, a temperature which meets all requirements at that early hour. The amount of fresh air supplied by the fan corresponds with the temperatures given, and is about 1,600,000 cubic feet per hour.

A series of experiments to ascertain the amount of air delivered by the fan, in which both Biram's and Casella's anemometers were used, gave the following results:

First Series, October 29, 1870.

| | |
|---|---|
| HP. of steam engine . . . . . | 8 |
| Pressure of steam . . . . . | 31 lbs. to square inch. |
| Strokes of the engine per minute . . | 91 |
| Diameter of the fan . . . . . | 7 feet 6 inches. |
| Revolutions of the fan per minute . . | 273 |
| Velocity of air through the fan per second . . . . . | 10·83 feet. |
| Volume of air delivered per hour through the fan . . . . . | 1,722,600 cubic feet. |

The volume of air, measured with anemometers at the mouths of the chambers under the same conditions, was, per hour—

| | Cubic Feet. | | Feet. | |
|---|---|---|---|---|
| South-west chamber . | 352,200 | velocity = | 6·30 | per second. |
| South-east „ . | 339,900 | „ = | 5·50 | „ |
| East „ . | 468,000 | „ = | 6·50 | „ |
| North front „ . | 402,000 | „ = | 5·00 | „ |
| | 1,562,100 | | | |
| Leakage and friction | 160,500 | | | |
| | 1,722,600 | | | |

SECOND SERIES, OCTOBER 31, 1870.

| | |
|---|---|
| HP. of the steam engine . . . . | 8 |
| Pressure of steam. . . . . | 32 lbs. per square inch. |
| Strokes of the engine per minute . . | 99 |
| Diameter of the fan . . . . . | 7 feet 6 inches. |
| Revolutions of the fan per minute . | 297 |
| Velocity of air through the fan per second . . . . . | 11·60 feet. |
| Volume of air delivered per hour through the fan . . . . . | 1,845,000 cubic feet. |

The volume of air, measured with anemometers at the mouths of the chambers under the same conditions, was, per hour—

| | Cubic Feet. | | Feet. | |
|---|---|---|---|---|
| South-west chamber . | 429,840 | velocity = | 7·83 | per second. |
| South-east „ . | 360,720 | „ = | 5·83 | „ |
| East „ . | 496,800 | „ = | 6·90 | „ |
| North front „ . | 441,540 | „ = | 5·50 | „ |
| | 1,728,900 | | | |
| Leakage and friction | 116,100 | | | |
| | 1,845,000 | | | |

On both days there was a slight breeze from the south.

Not being satisfied with the foregoing experiments, the Author made another series of observations, to ascertain whether the difference between the amount of air measured at the fan and the amount of air measured at the mouth of each chamber could be an error of the previous series; but the new series of these measurements, of which the following is a mean, gives nearly the same result, and therefore this difference may be accounted for by leakage and friction through the channels.

THIRD SERIES, NOVEMBER 19 to 23, 1877.

Wind, south west, strong.

| | |
|---|---|
| External temperature . . . . . | 43° Fahrenheit. |
| Pressure of steam in the boiler . . . | 35 lbs. per square inch. |
| Strokes of the engine per minute . . | 92 |
| Revolutions of the fan per minute . . | 276 |
| Diameter of the fan . . . . . | 7 feet 6 inches. |
| Area of the opening . . . . . | 44·18 square feet. |
| Velocity of air through the fan per second | 11·70 feet. |
| Volume of air delivered per hour through the fan . . . . . | 1,846,800 cubic feet. |

The volume of air, measured at the mouths of the chambers under the same conditions, was, per hour—

| | Cubic Feet. | | Feet. |
|---|---|---|---|
| South-west chamber | 502,200 | velocity = | 9·10 per second. |
| South-east „ | 309,600 | „ = | 5·80 „ |
| East „ | 419,760 | „ = | 5·80 „ |
| North front „ | 488,000 | „ = | 5·83 „ |
| | 1,719,560 | | |
| Leakage and friction | 127,240 | | |
| | 1,846,800 | | |

A series of measurements of the volume of air entering and escaping from the class-rooms, indicated that the mean velocity of the incoming air was 4 feet per second, and of the outgoing air 5 feet.

In the south-west block the result of experiments in one class-room was as follows:

| | |
|---|---|
| Capacity of the room. . . . . | 32,000 cubic feet. |
| Area of inlet from the apparatus . . | 7 square feet. |
| Area of outlet into the extraction shaft | 4½ square feet. |
| External temperature . . . . . | 40° Fahrenheit. |
| Temperature of the class-room . . . | 57° „ |
| Temperature of incoming air at the mouths of the openings . . . . | 75° „ |
| Temperature of the outgoing air . . | 64° „ |
| Temperature of the extraction shaft . | 64° „ |
| Mean velocity of the incoming air . . | 5·88 feet per second. |
| „ „ outgoing air . | 7·50 „ „ |
| Volume of air supplied per hour . . | 148,536 cubic feet. |
| „ „ extracted „ „ . . | 121,500 „ „ , to which must be added the air escaping under the risers of the seats not measured. |

Observations show that on account of the air being drawn by the fan from so high a level, the amount delivered varies somewhat according to the direction and force of the wind: the situation of the building on a high hill has also a great deal to do with this. The lowest delivery of air, when the average speed of the engine was 90 strokes per minute, was 1,350,000 cubic feet per hour. Valves are fixed in all the subterranean passages, so that the power may be increased, or otherwise, in any particular portion of the building.

The amount of fuel consumed in working the apparatus for six sessions has been as follows:

| | Tons. | Cwt. |
|---|---|---|
| Session 1871–72 . . . . . | 448 | 15 |
| „ 1872–73 . . . . . | 427 | 10 |
| „ 1873–74 . . . . . | 372 | 12 |
| „ 1874–75 . . . . . | 458 | 18 |
| „ 1875–76 . . . . . | 462 | 19 |
| „ 1876–77 . . . . . | 404 | 4 |

In calculating the allowance for the heating surface contained in this building, assuming an average of eight hours' firing per day, and comparing the amount with the quantity of fuel consumed, it will be seen that the average consumption of 2 tons 3 cwt. per day bears a just proportion to the number of feet of heating surface, and to the cubic contents, 2,035,000 feet, of the building; but as an essential part of the apparatus is the regulated supply of fresh air, amounting to 1,800,000 cubic feet per hour, this must be added in order to give a fair estimate of the power of the apparatus. Thus the air moved and warmed by the average daily consumption of 2 tons 3 cwt. of coals is equal to 3,835,000 cubic feet per hour.

The staff consists of one engineer and one stoker, with the assistance of a supernumerary stoker during the winter months.

The cost of maintenance, with a sum set aside for occasional repairs, is about £500 per annum; the average cost of coals in Scotland being taken at 13*s.* per ton. The total cost of this application, including the construction of the air chambers, air channels, vertical flues, and extracting shafts, has been about £17,000.

In conclusion, the Author may, perhaps, be allowed to state that this application has given general satisfaction; and is, probably, the best arrangement that could have been adopted under the circumstances. The successful issue is certainly attributable, in a great degree, to the persevering labours of the eminent Professors who formed the Ventilating Committee, and to their Architect, the late Sir George Gilbert Scott, R.A.

The communication is accompanied by several diagrams, from which Plate 6 has been compiled.

# APPENDIX.

## GLASGOW UNIVERSITY

### I.—Average Monthly Temperatures at 8 A.M. Session 1871–72.

| Name of Class-rooms. | November. | | December. | | January. | | February. | | March. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | External. | Class-rooms. | External. | Class-rooms. | External. | Class-rooms. | External. | Class-rooms. | External. | Class-rooms. |
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| Humanity . . | 40 | 51 | 38 | 52 | 36 | 52 | 34 | 50 | 35 | 57 |
| Greek . . . . | „ | 50 | „ | 51 | „ | 50 | „ | 51 | „ | 53 |
| Logic . . . . | „ | 51 | „ | 51 | „ | 51 | „ | 50 | „ | 52 |
| Moral Philosophy | „ | 51 | „ | 52 | „ | 53 | „ | 51 | „ | 54 |
| Natural Philosophy | „ | 56 | „ | 55 | „ | 54 | „ | 54 | „ | 56 |
| Physical Laboratory . . . . | „ | 54 | „ | 54 | „ | 54 | „ | 54 | „ | 54 |
| Mathematics . | „ | 50 | „ | 51 | „ | 52 | „ | 51 | „ | 53 |
| Astronomy . . | „ | 51 | „ | 52 | „ | 52 | „ | 50 | „ | 53 |
| Civil Engineering | „ | 50 | „ | 51 | „ | 52 | „ | 50 | „ | 53 |
| English Literature | „ | 51 | „ | 50 | „ | 50 | „ | 51 | „ | 51 |
| Natural History . | „ | 54 | „ | 54 | „ | 53 | „ | 53 | „ | 56 |
| Divinity hall . . | „ | 53 | „ | 53 | „ | 53 | „ | 54 | „ | 57 |
| Hebrew . . . | „ | 55 | „ | 55 | „ | 54 | „ | 53 | „ | 55 |
| Ecclesiastical History . . . . | „ | 54 | „ | 54 | „ | 54 | „ | 54 | „ | 55 |
| Biblical Criticism | „ | 57 | „ | 55 | „ | 55 | „ | 55 | „ | 57 |
| Scottish Law . . | „ | 53 | „ | 54 | „ | 53 | „ | 51 | „ | 54 |
| Conveyancing . | „ | 52 | „ | 52 | „ | 54 | „ | 53 | „ | 55 |
| Chemistry Class-room . . . | „ | 56 | „ | 54 | „ | 53 | „ | 52 | „ | 54 |
| Chemical Laboratory . . . . | „ | 53 | „ | 54 | „ | 51 | „ | 54 | „ | 55 |
| Materia Medica . | „ | 50 | „ | 53 | „ | 54 | „ | 50 | „ | 56 |
| Anatomy Class-room . . . | „ | 51 | „ | 52 | „ | 53 | „ | 53 | „ | 53 |
| Anatomical Laboratory . . . | „ | 48 | „ | 49 | „ | 51 | „ | 50 | „ | 52 |
| Practice of Physic | „ | 53 | „ | 54 | „ | 53 | „ | 52 | „ | 54 |
| Surgery . . . | „ | 54 | „ | 54 | „ | 54 | „ | 51 | „ | 55 |
| Midwifery . . | „ | 51 | „ | 52 | „ | 52 | „ | 51 | „ | 55 |
| Forensic Medicine | „ | 52 | „ | 53 | „ | 54 | „ | 53 | „ | 56 |
| Physiology . . | „ | 52 | „ | 53 | „ | 54 | „ | 53 | „ | 55 |
| Library . . . | „ | 53 | „ | 55 | „ | 54 | „ | 55 | „ | 55 |
| Museum (Sunday) | „ | 50 | „ | 52 | „ | 51 | „ | 52 | „ | 53 |
| Reading-room . | „ | 52 | „ | 52 | „ | 51 | „ | 50 | „ | 52 |
| Dr. A. Thomson's room . . . | „ | 57 | „ | 57 | „ | 56 | „ | 56 | „ | 56 |
| Examination hall | „ | 51 | „ | 52 | „ | 55 | „ | 54 | „ | 54 |

II.—AVERAGE MONTHLY TEMPERATURES at 8 A.M. Session 1872–73.

| Class-rooms. | November. | | December. | | January. | | February. | | March. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | External. | Class-rooms. | External. | Class-rooms. | External. | Class-rooms. | External. | Class-rooms. | External. | Class-rooms. |
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| ty . . | 38 | 53 | 36 | 52 | 39 | 52 | 31 | 51 | 35 | 54 |
| . . . | „ | 53 | „ | 51 | „ | 51 | „ | 50 | „ | 51 |
| . . . | „ | 52 | „ | 52 | „ | 52 | „ | 50 | „ | 51 |
| hilosophy | „ | 55 | „ | 53 | „ | 54 | „ | 53 | „ | 52 |
| Philosophy | „ | 56 | „ | 54 | „ | 55 | „ | 55 | „ | 55 |
| . Labora- . . . | „ | 54 | „ | 55 | „ | 55 | „ | 54 | „ | 54 |
| atics . . | „ | 53 | „ | 52 | „ | 51 | „ | 52 | „ | 52 |
| ay . . | „ | 54 | „ | 52 | „ | 52 | „ | 52 | „ | 52 |
| gineering | „ | 54 | „ | 52 | „ | 52 | „ | 51 | „ | 51 |
| Literature | „ | 51 | „ | 53 | „ | 54 | „ | 52 | „ | 54 |
| History . | „ | 54 | „ | 51 | „ | 53 | „ | 53 | „ | 54 |
| hall . . | „ | 56 | „ | 54 | „ | 53 | „ | 54 | „ | 56 |
| . . . | „ | 56 | „ | 54 | „ | 54 | „ | 54 | „ | 54 |
| atical His- . . . | „ | 56 | „ | 54 | „ | 54 | „ | 54 | „ | 54 |
| Criticism | „ | 56 | „ | 54 | „ | 56 | „ | 56 | „ | 56 |
| Law . . | „ | 54 | „ | 53 | „ | 54 | „ | 53 | „ | 55 |
| ncing . | „ | 56 | „ | 54 | „ | 55 | „ | 54 | „ | 56 |
| ry Class- . . . | „ | 54 | „ | 53 | „ | 52 | „ | 53 | „ | 54 |
| al Labora- . . . | „ | 54 | „ | 55 | „ | 51 | „ | 53 | „ | 54 |
| Medica . | „ | 54 | „ | 53 | „ | 53 | „ | 52 | „ | 55 |
| y Class- . . . | „ | 53 | „ | 52 | „ | 54 | „ | 54 | „ | 54 |
| cal Labor- . . . | „ | 50 | „ | 51 | „ | 51 | „ | 50 | „ | 52 |
| of Physic | „ | 55 | „ | 55 | „ | 53 | „ | 53 | „ | 54 |
| . . . | „ | 54 | „ | 54 | „ | 54 | „ | 52 | „ | 55 |
| ry. . . | „ | 53 | „ | 53 | „ | 52 | „ | 51 | „ | 53 |
| Medicine | „ | 53 | „ | 54 | „ | 54 | „ | 53 | „ | 55 |
| gy . . | „ | 54 | „ | 54 | „ | 55 | „ | 53 | „ | 55 |
| . . . | „ | 55 | „ | 55 | „ | 54 | „ | 55 | „ | 55 |
| (Sunday) | „ | 54 | „ | 53 | „ | 52 | „ | 52 | „ | 53 |
| -room . | „ | 52 | „ | 52 | „ | 51 | „ | 51 | „ | 54 |
| Thomson's . . . | „ | 57 | „ | 55 | „ | 57 | „ | 55 | „ | 55 |
| ation hall | „ | 58 | „ | 54 | „ | 55 | „ | 56 | „ | 56 |

[Professor JAMES THOMSON,

Professor JAMES THOMSON, transmitting through the Secretary his remarks, premised that the problem of how to provide good means for warming and ventilating any such set of rooms as those comprised in the buildings of a college, or a university, was a difficult one. Information in respect to a large undertaking of this kind was very important, whether to serve as a guide for showing courses which might advantageously be followed in future, or as a beacon for indicating what should be avoided. He said the arrangements carried out for warming and ventilating in Glasgow University were to be regarded as only in a moderate degree successful. They were far from admitting of being contemplated with satisfaction, and this for various reasons. In the class-rooms of several of the large classes the scheme turned out to be quite inadequate as to ventilation. In some of them, which were crowded with students, after strong complaints of the oppressiveness of the air, it had become necessary to have recourse to the opening of windows in winter weather to mitigate the evil. But the opening of the windows completely subverted the intended ventilation arrangements, and rendered them in the main nugatory. Such results, he said, inevitably must be entailed by the abandonment, in the executed scheme, of the originally intended essential arrangement, that besides the hot fresh air, cold fresh air should be supplied to each class-room, with means for mixing it.[1] The abandonment of this provision was a mistake fatal to the success of the scheme; and if the adoption of the provision would have proved too difficult, it would have been better to have dropped the scheme as a whole, and to have entered on designs for the undertaking in some other way altogether. To ventilate a crowded class-room, new air must be supplied, amounting in volume to many times the contents of the class-room per hour. But if this air for ventilation is supplied hot from a system of conduits suitable for warming other class-rooms before the meeting of the students, or class-rooms with only a few occupants, the temperature in the crowded rooms must necessarily become intolerably high. The bodies of the occupants, with their breathing included, would make the room very hot, and would render the air badly vitiated, unless a large flow of new air were maintained, passing through the room in such way as to scour off the vitiated air from around them. Now obviously the air to be supplied for a crowded meeting must enter in large quantity, and at no higher tem-

[1] *Vide* No. 5 of the original recommendations of the Committee of Professors cited by Mr. Phipson near the beginning of his Paper.

perature than that of air desirable for surrounding the occupants, and for being breathed by them. But the air in the ducts which lead to some of the crowded rooms is, he said, ordinarily at about from 90° to 109° Fahrenheit, and some such temperature is requisite to provide sufficient warming effects in other rooms. In several of the class-rooms the hot ventilation air comes in by openings about half-way up the walls, and goes away in great part by passing clear over the heads of the occupants to wall-head outlets, without ever coming down for the use of the occupants, the cooler air tending to stagnate around them in the lower half of the room.

In the Paper the Author had stated that he "based the calculations of the size of all air passages, &c., both for outlet and inlet of the air, on a supply equal to six times the cubical space of the class-rooms in the hour as a minimum, or about 750 cubic feet per hour, per sitting." Now Prof. Thomson presumed that if this amount of ventilation by fresh air of suitable temperature were actually effected in the individual class-rooms, it would be unlikely that professors and students would make the complaints they did of deficient or faulty ventilation. He did not think, however, that any such supply is really given to the individual class-rooms generally. Last winter, for instance, in consequence of great complaints as to the ventilation of some of the crowded class-rooms, he was requested, with some of his colleagues, to act as a committee to examine into the subject. No exact quantitative experiments were made. The effort was rather, by examining into a few doubtful points as to the behaviour of the air, and as to the effects of opening or closing some of the valves or other passages, to find whether any palliative improvements could be devised or effected. A set of observations thus made, in one of the class-rooms specially complained of, happened to give clear indications which showed the change of air available to be very small indeed, in comparison with any such standard as 4, 5, or 6 times the volume of the class-room per hour. There were six inlet openings, about half-way up the walls of the room, for the admission of the ventilation air supply, which was warm as usual, and there were two valves near the ceiling for outlets, in addition to outlets in the risers under the students' seats. Smoke was produced by the burning of cotton waste or the like in a pan held up above the lecture-table. The wall-top outlets were left open for a considerable period, in order that the conditions and actions of the air so resulting might be found. The smoke arranged itself so as to form a well-marked thin stratum, which remained persistently at the level of the inlet orifices for the warm air, and

the result was obvious, that the warm ventilation air was floating like a canopy over the region to be occupied by the students and professor, and passing away by the wall-head outlets, while the original cold air remained stagnant in the lower part of the room. The wall-top outlets were afterwards closed, and then it was found that the cloudy stratum of smoke descended slowly, at some such rate as 2 feet in eight minutes. At any such rate as this, a long time would elapse, far more than an hour, before the contents of the class-room would be even once cleared out by the ventilation supply.

This, he said, was not offered as a very exact experimental result, nor as one tested by repetition for its confirmation; but he thought it was trustworthy enough to justify its being regarded as affording important indications. The smoky layer obviously indicated the level face of meeting of the cold stagnant air below, with the warm air floating above and passing from the inlets to the outlets while floating above the region to be occupied by the assemblage of people. Observations with thermometers above and below the smoky layer confirmed the view here stated.

The scheme as carried out, he said, involves the very objectionable feature that the air is conveyed through underground tunnels, of which the roof, the walls, and the bottom are thoroughly damp, and the bottom is in many places running with water. The entrance of moisture is especially objectionable in the hot-air tunnels. In some of these, water gathers at seasons when the heating is not maintained; but during the time of the College Session it is evaporated, and the subsequent accessions of water are also evaporated, so that the whole water passes with the ventilation air into the rooms. In one of these hot-air ventilation ducts, through which he had crept for inspection a few days previously, the floor was thoroughly covered with scale upon scale of pellicles obviously left behind by sheets of water, which, containing lime in solution, had successively dried up. Great evil had been experienced in the library and some neighbouring rooms from damp introduced in this way; but some amendments had lately been introduced in the arrangements for that part of the building. A very wet hot-air tunnel or chamber had, he understood, been drained, and some other changes had been made for abating the evil.

As a general rule, he asserted that the conveying of ventilation air by underground passages is highly objectionable, or gravely open to distrust. When this mode of conducting the air is taken, it is often impossible to make quite sure against the intrusion of foul emanations, gaseous or liquid, from sewers directly, or from

ground or shingle permeated by water and air of sewers. Indeed the scheme carried out for the University of Glasgow, he said, had not altogether escaped from exemplifying the unsuitableness of subterranean ventilating passages in this respect. At one time foul air had been met with in the building, and it was then found that under the ventilation tunnel there had been left an old sewer which had belonged to the dwelling-house of Gilmore Hill before the lands were acquired for the University, and that an opening had been casually made into that sewer, whereby the foul air had been admitted into the ventilation air for the building. This was of course immediately remedied, and he presumed there had since been no indication met with of the admission of foul air to any part of the ventilation ducts.

In conclusion, he had to say that while the arrangements carried into effect for warming and ventilating in the University of Glasgow were such as he could not recommend for imitation in other places, yet he would wish it to be borne in mind that unsatisfactory results in warming and ventilating were the rule, and not the exception, in public buildings, as also in dwelling-houses, throughout the world.

The problem of devising good warming and ventilating arrangements for such a set of buildings and apartments as those of a University, where large classes of students are in attendance on lectures, and engaged in practical work in laboratories and in other ways, he said had not yet been well solved.

Dr. ALLEN THOMSON said he should have scarcely ventured to speak upon a subject so foreign to all his knowledge and occupations, but for the circumstance that he had been the Chairman of the Building Committee of the Glasgow University during the construction of the apparatus which had been described. Indeed, from the year 1863 till the time that he left the University, more than a year ago, he had been to a certain degree in charge of the operations going on there, and he might therefore be supposed to know something of the apparatus in question, although he could scarcely pretend to any knowledge of the subject of ventilation and heating of buildings, at least practically; and he would be extremely averse to offer any decided opinion on a subject of such extreme difficulty. The result of his limited experience had been to confirm the remark of his former colleague, Professor James Thomson, that the problem of ventilating and heating (especially ventilating and heating together) large buildings had not yet been solved. At all events he would go so far as to say, that the application of such a mode of heating and ventilation as had been

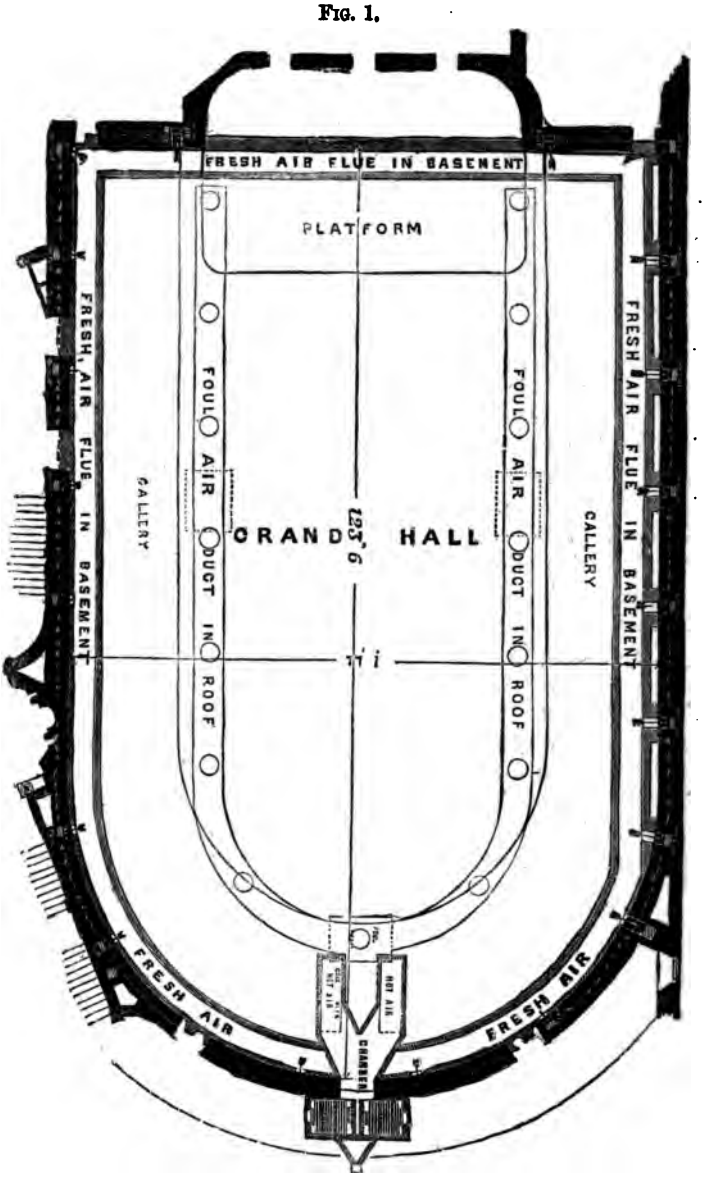
described should be regarded very much in the light of a great experiment. He would not, however, go the length of condemning the plan and apparatus as Professor James Thomson had done; he was rather inclined to give a different verdict with respect to it, and he thought that some of his colleagues, who had more knowledge of the subject than he had, would agree with him in saying that the Author's application of General Morin's system had been attended with considerable success. He was aware that a number of circumstances in the original construction had somewhat interfered with that success. The circumstance that the system was not matured until the whole of the plans of the building and drainage had been already set on foot, interfered considerably with the successful carrying out of some of the plans of the ventilating engineer, and it was only right to state that the same circumstance added largely to the original expense of the construction. With reference to the success of any general system of heating and ventilation, it was obvious that great variability was one of its most important attributes; and if he were to venture to criticise this one, it would be to say that it was too extensive, or too much upon one uniform plan throughout the whole building. One conclusion which he should be disposed to draw from the experiment was, that the modes of heating and ventilation should be very different according to the purposes that were to be served by the several parts of the building to which they were applied. In all such buildings there was a great distinction between class-rooms and halls for meeting on the one hand, and museums and libraries on the other; and he thought it was an original error on the part of the Sub-Committee of Professors to apply the system to the libraries and museums. With reference to the class-rooms and halls for meeting (and in this he believed that a majority of the Professors who were conversant with the management of the building would express the same opinion), the plan had been followed with good results. He was not aware of the experiments that Professor Thomson had described in his communication. They certainly appeared to indicate some defect in the room to which he had referred, but had not named. That was not in accordance with his own experience with respect to most of the class-rooms. On the contrary, he should be inclined to say with reference to other class-rooms which he had known, that the quality of the air was most satisfactory; that there was generally comfort with regard to heat, and freshness of air; and that the health of the students had been extremely good. Those circumstances appeared to be in favour of the mode of combined heating and ventilation, by the forced introduction and extraction of air, in places resorted

to by a large body of students. He was partially aware of the defect to which Professor Thomson had referred in one of the class-rooms. He presumed it was the Latin class-room, in which there were upwards of three hundred students. He believed that the inlets and outlets in that class-room were not calculated for so large a number, and that both increased force of introduction and increased size of the apertures would be required in order to provide proper ventilation for the room. That, however, should be considered as an exceptional case. He agreed with Professor Thomson that it was greatly to be regretted that the plan of combining the introduction of warm and cold air had not been followed out. On the whole he should be inclined to apply in museums and libraries, in which large numbers of persons were not to be congregated, a system of heating which would give gentle warmth, such as that derived from coils or other forms of wide hot-water pipes, within the rooms themselves, not attended with the introduction of large bodies of air from without. In the case of museums, the latter plan was especially to be avoided, on account of the difficulty of controlling dust and moisture.

Mr. CONSTANTINE said that the Paper had involved a great deal of patient research. The instructions of the Sub-Committee of Professors to the architect appeared to have been based upon General Morin's theory, which was a very complicated one. However good it might be for warming buildings, it had broken down in summer when a great quantity of fresh air was required. The expense of carrying out the plan was stated to be £17,000. He had recently the warming of the Manchester Pantechnicon, comprising fifty-four rooms, and the Royal Exchange, and he was able to say, after a very close calculation, that the cost of warming and ventilating such a building as the Glasgow University, instead of being £17,000, ought to have been £1,360. If what might, for the sake of distinction, be termed a natural system of ventilation had been carried out, with efficient air-warmers placed in different parts of the building, the warm air channels would act as fresh air ducts, and an ample supply of fresh air would have been obtained during the summer, which was a most important consideration. The system of coils, with a fan and an engine to drive the air, was a very expensive mode of introducing it. When the Royal Exchange at Manchester was planned, it was intended to force the air in by an engine and fan; but when the building was in course of erection, the architects asked him what he would suggest. That was soon after he had warmed the Free Trade Hall. Two convoluted stoves were fixed in the basement, where the engine and fan were intended to be erected, and drew the fresh air from a

height of 100 feet at the top of the building, and the system acted simply and easily. The ventilating and warming arrangements were shown in Fig. 1. Under the basement floor was a flue 3 feet

FIG. 1.




Plan of the Free Trade Hall, Manchester.

broad by 2 feet 2 inches wide, directly supplied with fresh air from the outside. From this flue were carried up eighteen vertical shafts, each 2 feet by 1 foot 2 inches in the thickness of wall, delivering fresh air above the heads of the people in the gallery. For the extraction of the vitiated air, openings were provided round the fifteen sunlights into two lath-and-plaster ducts, measuring each 4 feet 3 inches broad by 3 feet 9 inches wide, along the inside of roof, uniting at end opposite platform into an upright shaft 7 feet 9 inches broad by 5 feet 7 inches wide inside. This main shaft was surmounted by a cowl moved easily by the wind, and had only the movable portion exposed above the roof. The inlet of fresh air was ample; but the exit for foul air was contracted, the cowl having only about the sectional area of one of the two ducts which it cleared. Although the warm air was all delivered in one place, in a few minutes the temperature was the same all over the hall. The temperature for the class-rooms was about equal to what was maintained in the Royal Exchange. The temperature given in the table was too low for class-rooms. In the first year the temperature in the class-rooms was only 16¾° above that of the external air, and in the second year 17½°. It ought to be raised 25° in order to make the rooms thoroughly comfortable in severe winter weather. It appeared that 2 tons 3 cwt. of fuel was consumed per day, the number of cubic feet to be dealt with being 2,035,000. In the Royal Exchange the number of cubic feet were 1,500,000, for which 2½ cwt. of coke per day were sufficient. Supposing the building to be warmed by four large convoluted stoves it would not consume more than 5 cwt. of coke. The immense shafts were not absolutely necessary. Perhaps the best illustration of what might be called the natural system was in the Free Trade Hall, where an ample supply of fresh air was obtained during the summer months. He had brought a model of the convoluted stove, and should be glad to show the plans to any member who desired to see them.

Dr. Allen Thomson desired to add that he thought the Author had underrated the bulk of the building. He made it much larger. It was a range of 1,300 feet in length, with an average breadth of 50 feet, and a height of 60 feet.

Mr. Cowper did not consider himself an authority on ventilation; but in certain engineering cases, when erecting Engine-Shafting, &c., he believed he might say he had been called upon to ventilate a building, and had succeeded tolerably well. The old Post Office and the Inland Revenue Office were two of the largest buildings with which he had been concerned. It appeared to him that some

of the conclusions of the Scientific Committee who went into the matter theoretically, were in fact old ideas, and some of the novel ideas were found to be impracticable, and had not been carried out. In several cases there had been something like a division by 3, which rather tended to interfere with any scientific conclusion. No doubt the Author had treated the matter in a thoroughly practical way, and perhaps had neglected some of the theoretical conclusions. Had he been given a clear field, with full liberty to ventilate and warm the building as he liked, without the interference of so many persons, he would no doubt have done it at a much less cost than £17,000, and £500 a year for maintenance, coal being only 13*s.* a ton. The Author had not followed General Morin; nor had he adopted the quantity given by the committee of 0·6 cubic foot of air per second for each individual. The area of opening was to have been $\frac{2}{3}$ square foot, but that being impossible it was practically carried out at $\frac{1}{18}$ square foot. The Author was to be congratulated on having arrived at such satisfactory results. As to the extent there might be differences of opinion; a quantity of fresh air had been obtained, and although some of the rooms were a little too warm, that no doubt could be remedied. A crowded class-room, where a popular professor was lecturing, was very different from one nearly empty; if air of the same temperature were pumped into both, one would be at fever heat, while the other would be only just comfortable. If, instead of raising all the rooms to a temperature suitable for an empty one, the fire was let down, and a lower temperature was made the rule, the heating of the cooler rooms could be easily supplemented by a few coils of pipes round them. Perkins's hot-water pipes were the most convenient, because they could be carried almost anywhere around the walls, and be run into the window recesses, and thus tended to prevent the cataract of cold air that often came down so unpleasantly from walls and windows in frosty weather where there was no apparatus. Although so many eminent names had been mentioned in the Paper, that of Dr. Arnott and Dr. Reid, both of whom strongly advocated forced ventilation, had been omitted. With regard to the construction, there appeared to him to be two complete systems. First, there was an elaborate system of flues below the bottom of the building. Of course full possession of the basement was necessary for that. He presumed that orders had been given to the architect to carry out the system, or he would not have subjected the walls to such severe treatment. That being granted, and the money assured, there was a complete system of hot air to come up all the

vertical flues. With a fan, or any mode of forcing air into a room, it appeared to him that almost all difficulty of ventilation vanished. The late Mr. Oldham, of the Bank of Ireland, when managing the bank in Dublin put up a large wooden pump with a leather packing, by which air was pumped into the printing office. When the cholera was raging in the neighbourhood, he used to say that he pumped it out of the windows, and in fact, no cases occurred in the building, which was thoroughly ventilated and wholesome. He had carried out the same plan at the Bank of England. By means of a pump, 4 feet square and of 5-feet stroke, air was pumped into the building. It was a favourite idea of Mr. Oldham to put a pocket-handkerchief saturated with Eau de Cologne in the passage, when the scent would be at once perceived all over the printing offices, showing that there had been a complete distribution of the air. Some years ago Mr. Cowper was consulted about a Town Hall, where the inconvenience of the cold air pouring down from contact with the windows was so marked, that in the gallery, where the best and most expensive seats were placed, the temperature during a concert was 42° Fahrenheit. He suggested, as a temporary expedient, a row of gas jets on the window-sills: these had the effect of preventing the cold air from coming down, but it did not warm the hall, nor was it intended to do so. The evil was local, and required a local cure. Unless warm air, hot water, or gas were applied near the windows, cold air would assuredly come down from them. With regard to the advisability of the chamber underground being kept dry, he agreed with the Author of the Paper; but it appeared from what had been stated, that the chamber was damp. He might mention that the late Sir Charles Fox allowed a draughtsman of his to arrange a warming apparatus for his offices at Smethwick. Unfortunately, there was a flue underground in a gravel bed, which was very wet, with a sloping field down to it—also a gravel bed. The flue could not be dried, and the moisture continually evaporating from it into the offices, the water condensed against the windows, which had fixed cast-iron sashes with small openings, so that instead of the apparatus being a ventilating one, it was a distilling apparatus: the water ran down on the window-sill, and there were puddles half a yard square on the floor. The effect upon the health of the draftsmen was most injurious; and colours, such as Prussian blue, which was rather brittle when dry, could be bent without breaking. In summer, it became a habitation for frogs, and when the steam was turned on, there was "an ancient and a fish-like smell." In a large building where power could be

used, there was little difficulty in applying hot-water pipes in each room so as to have as much heat as was required in each place—not too much in one, or too little in another. The foul air could be blown out through the cracks of the windows and the doors, and if they were not enough, perforated zinc could be put on the tops of the sashes of the windows. The benefit of a little pressure in the room was that all draughts of cold air from the windows and doors were prevented. If they were excluded, by forcing out the foul air instead of allowing the cold air to be drawn in, it was a great comfort. By using an extracting shaft, as in a coal pit, a partial vacuum was made in the room to draw out the foul air, and the advantage of preventing cold draughts was lost. Besides, the expense of the flues was doubled, and much coal had to be burnt. In that way the candle was burnt at both ends, by sucking out the foul air whilst the fresh was being forced in. If the fresh were forced in, the foul must go out. Where gas-lights were largely employed, as in workshops, it was worth while to put small funnels over the top of the burners, taking pipes from them into the chimneys. That had been done in the underground offices of the Post Office, where gas burned continually; and in that way the products of combustion were carried off. With regard to the table at the end of the Paper, he observed that the temperature in the majority of the rooms was below 53°. This, he thought, was too low for comfort. The rooms in the morning ought to have a temperature of not less than 60°, and the artificial heat should be lowered when the natural heat of the bodies of the students came into play. Possibly, however, notwithstanding the enormous amount of hot-water piping, the large quantity of air pumped into the rooms might keep down the temperature, so that it was not practicable to get it higher than quoted in the table. He had observed the effect of a pair of large screw fans going in opposite directions, and the current produced by them was very feeble. More work could be obtained by a centrifugal fan. He had made three hundred experiments with centrifugal fans, and found that at low pressure not more than 50 or 60 per cent. of useful effect could be obtained; but at somewhat higher pressure he had obtained 75·16 per cent.

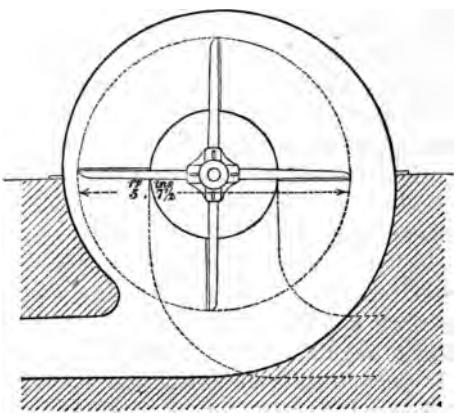
He desired to say a few words on what appeared the simplest mode of artificial ventilation without incurring excessive expense. First, the air should, of course, be drawn from the purest source available. A large roof on the top of the building without chimneys near was a good place from which to get air, the air in the streets being vitiated. Secondly, there should be a centrifugal

fan in a convenient situation, near the engine, not necessarily in the middle of the building. The fan should draw the air from the best source, and drive it at a moderate velocity through medium-sized pipes, which he would call high-pressure mains, which should be always charged. Air could then be sent to any part of the building. All that would be required would be to draw off from the main as much air as was wanted for each room by a distribution pipe, full of holes, which could run round the skirting, or along the cornice or on the floor, and through which the air would ooze into the room without producing a draught. The distribution pipes must not have large holes in them, but ¾-inch holes, at intervals of an inch or two. Professor Faraday many years ago showed that a velocity of 2 feet per second did not produce a perceptible draught. This could be seen by taking a sheet of tracing paper and moving it through the air at that velocity, in which case it would take an angle of 45° from the vertical, and without any draught or unpleasant effects being produced. The way to regulate the air to each distribution pipe from the main was to provide an opening from the main into the distribution pipe, and supply it with a small slide, and when the right quantity of air was provided, then to solder the slide fast. In that way the right quantity would be obtained for each room. A piece of tracing paper could be put in front of a hole, to show the pressure by the angle at which it stood. The velocity of the air in the mains might be 50 or 60 feet per second. In the Glasgow University it was only 11 or 12 feet, no doubt because the Author had graduated the size of the pipes and the velocity of the air, since there was a free opening from the fan into the room. Mr. Cowper had not got that arrangement by his system. He had the means of throttling the air under pressure from the main into the distribution pipes, which gave a power of regulation, and saved the expense of large passages and culverts, and of cutting the walls so much and making large shafts. A pipe 1 foot square, or so, could be introduced into the corner of a building without great expense, and the cost was less.

Fig. 2 showed a fan for ventilating the stamping department of the Inland Revenue Office. The whole of the blades could deliver air at all times throughout their revolution, the spiral outline of the casing starting from the bottom, at the circle formed by the tips of the blades, and gradually opening out, as an arithmetical spiral, to the width of the mouth of the fan. The corner was rounded, to prevent the air meeting a sharp edge. In this way a perfectly silent fan was formed, and one capable of propelling a

large quantity of air. Captain Ericson had set out fans very like this forty years ago. Mr. Cowper had constructed many of them. He had made about three hundred experiments with one large fan; in some of the experiments there was a central curved boss, and in

FIG. 2.



others, screw blades on each side in the eye, neither of which were of much use. The percentage of useful effect varied much with different pressures up to one equivalent to a column of water of 9 inches, and varying areas of opening. In some cases, the percentage of useful effect, calculated by the area of opening, and the velocity due to the pressure at the exit, amounted, as had been stated, to 75·16 per cent. of the power expended, which power was calculated from the average of three good indicator diagrams in every case, the velocity of the air being about $\frac{9}{10}$ of the velocity of the tips of the blades.

Mr. IMRAY remarked, through the Secretary, that more than thirty years ago he had been engaged in a great number of works of warming and ventilating, having been at that time associated with one who might be called the Apostle of Ventilation, Dr. Boswell Reid. The works referred to included the State apartments of Buckingham Palace; the Italian Opera in the Haymarket; the prisons of Perth, Edinburgh, and Belfast; St. George's Hall, Liverpool; the Industrial Schools at Swinton, near Manchester; the Royal yachts; several hospital ships; the Courts of Law at Westminster and the Old Bailey; and the Houses of Parliament.

The Author had truly said that there were no physical difficulties in the way of ventilation, for air, like any other inert body, would go in any required direction by the application of suitable

force. The real difficulties encountered by the engineer who undertook warming and ventilating works were of what might be called a moral kind. The first of these arose from the fact that the warming and ventilation of a structure was almost always an afterthought. The plans were completed, often the structure was far advanced, or even finished, before a thought was given to arrangements for making it comfortable and salubrious. It then became almost impossible to carry out desirable modifications without materially interfering with the accommodation and design; and the engineer was, therefore, driven to do the best he could under the circumstances, though that was far from the best that he could do if left untrammelled. The next difficulty of the moral order which the engineer had to encounter, a difficulty that presented itself even when ventilation was studied *ab initio*, was to prevail upon the architect to subordinate beauty to utility. Because an air-chamber might lower a ceiling a few inches, because an air-inlet might involve certain perforations, or an air-outlet might require a hole, the architect would condemn the tenants of his structure to discomfort and suffering, holding them to be amply compensated by elegant proportions or tasteful decorations. It was undoubtedly the civil engineer who had taught the architect that the structure must, in the first place, be fully suited to its purpose, and might then, in the second place, but not before, be made to look pretty. And it was only since the engineer had given the example of structures eminently fitted for their purposes in respect of accommodation and strength, and at the same time stately and beautiful, that the architect had condescended to bestow nearly as much consideration to the useful as he had hitherto done to the beautiful. At the time when he was engaged on works of the kind referred to, there was an incessant struggle against the notion that a thing could not be made to look well if it also acted well. Another difficulty, also of the moral kind, in the way of successful ventilation, consisted in the impossibility of satisfying everyone. For several years he had superintended the ventilation of the temporary House of Commons, which was occupied while the new building was in course of erection. The ventilation of this chamber was acknowledged to be absolutely perfect, the engineer having had perfect freedom of action in carrying out his plans. The air supplied was sifted, washed, partly warmed, mixed and tempered, and admitted to the House in a gentle and uniformly-diffused stream; it could be supplied in almost any desired volume, and at almost any desired temperature, within reasonable limits, and suited to a House composed of thirty or of five hundred members.

But with all this it was impossible to satisfy many of those for whom such provision had been made. One member perhaps complained of cold, while his neighbour complained of overpowering heat. In the midst of these difficulties the Speaker took the matter in his own hands, gave orders as to the temperature, and those orders were strictly complied with.

If a chamber or building had no pretentions to ventilation, its occupants did not complain, because they knew it was bootless; but the moment it was said to be scientifically ventilated everyone complained because the climate was not exactly what he desired. It might thus be readily understood that ventilation, as had already been remarked during the discussion, never got the credit of succeeding. Those who were satisfied did not care to express their content, they took it all as a matter of course; while the discontented minority cried aloud and led the outside world to believe that the whole thing was a failure.

With respect to the particular work under consideration, the warming and ventilating arrangements of Glasgow University, the engineer had evidently been hampered by some of the difficulties above referred to, and would probably have done some things differently if he had been free to choose. It could not be supposed, for instance, that he preferred to employ as fresh-air conduits, channels underground, subject to damp and to noxious emanations from sewers. He undoubtedly did right in taking fresh air from a high elevation, and in forcing it by a fan or propeller. As Mr. Cowper had justly remarked, a slight elevation of the pressure in an inhabited apartment had the beneficial effect of preventing all in-draughts, and making sure that the only air supplied was that which could be controlled and tempered as desired. The *plenum* supply presented also another advantage, likewise referred to by Mr. Cowper, that it rendered unnecessary special arrangements for the discharge of foul air. Force a proper supply in, and provide outlets for discharge, and the climate of the room might be controlled as desired.

Whether fresh air was supplied under a little pressure, or whether foul air was extracted by slight rarefaction, as by a chimney draught, or whether both these forces were applied together, there must always be a difficulty about the arrangement of the actual fresh-air inlets. As a matter of necessity, if these were near the occupants, they must be of very large area, otherwise there would be such velocity of flow as to give the current the character of a local draught, alike unwholesome and unpleasant. The currents also must be broken up and dif-

fused, so as to provide a slow and gentle exchange of air without any perceptible movement. In order to provide for this in some cases, as in the temporary House of Commons before referred to, the whole floor had been perforated and covered by a thick hair carpet of loose texture. This perfectly served the purpose so far as regarded diffusion and suppression of currents. The only objection was that there would always be deposits of dust from the feet of the occupants, and it was not desirable that the fresh air supply should become vitiated at its very ingress. Where there were steps or stages of various elevations, or vertical screens or partitions, a well diffused supply could be obtained by making their surfaces porous, as in the form of gratings with some open fabric behind them; and in an apartment of moderate dimensions the whole supply might come through a porous skirting presenting a considerable surface. This, in his experience, had proved by far the best means of providing a supply of air for an apartment. The vertical surfaces did not harbour dust and dirt like the horizontal surfaces, and they were usually distant by a few feet from any of the occupants. Unfortunately architects had almost insuperable objections to open work at the base of a wall; they had not yet learned to look on it as a necessity, as much as a door, window or fireplace; and until they did so, they would not endeavour to make it ornamental as well as useful. It was probably in consequence of the difficulty of getting such open work at the lower level, that the Author, as well as other ventilating engineers, had had recourse to fresh-air inlets at a high level. This, in his opinion, was a grave error; and he only ventured to say so after many experiments of the kind referred to by Professor Thomson, which had satisfied him that such an arrangement was worse than useless. The emanations from the body, as well as the products of combustion from lights, were always warmer than the surrounding air, and must therefore rise. If while they rose the fresh air was descending, it must mingle with them and become contaminated before it reached the persons who were to breathe it. If, on the other hand, the air supplied was itself warm, it would ascend along with the foul air, and never reach the persons for whose use it was provided. It was a fallacy to suppose that because the inlets were removed to some height above the occupants the inflowing currents would be broken and retarded by diffusion in their descent; for, if the supply was colder than the air in the room, it would descend like a cataract from the inlet, and, if it was of equal or of higher temperature, it would never descend at all.

With the exception of the arrangement that had been adopted for fresh-air supply to the individual rooms, the Author's plans, as carried out in the Glasgow University, appeared to be well designed, and should be successful so far as success could be attained in any such work. In a work in which he had been recently associated with the Author, every credit was due to him for the way in which he met and overcame very serious difficulties; and probably if the Author had been more free in dealing with the Glasgow University there would not have been any ground for some of the objections that had been raised to his plans.

Mr. THORNYCROFT said that the warming and ventilation of the Glasgow University had presented great difficulties, in consequence of the long channels employed. He quite agreed with Mr. Imray with regard to the great advantage of having a slight excess of pressure in the building. He observed that the ratio of inlet to outlet had been made more uniform than had been suggested by the Committee who examined the subject before the building was erected. The inlet was to have had twice the area of the outlet; and it appeared to him that that ratio was partly intended to produce a slight excess of pressure within the building, compared with that outside. He thought that the recommendations of the Committee should have had the most careful consideration, as they had investigated the subject very fully. In considering the intention of the Committee, it appeared that, first of all, the pressure in the building should exceed the external pressure, and that the temperature of the air should be independent of the rate of change; that any room should be capable of having any amount of air passed through it, still maintaining the temperature at one definite point. Apparently the intention was that the hot air should remain first at the top of the room, and, as it cooled, gradually descend, so that the noxious air should be drawn out from the base of the room. That would probably be the effect if a room was heated by the air passing through it. With regard to the shortness of the conduits, where a room was self-ventilating—where there was an accidental ventilation—the channels were usually short, the air always taking the shortest way. It should always be borne in mind, in designing a ventilating apparatus, that the channels should either be short or large. He begged to offer a sketch of what appeared to him to be a way of overcoming the difficulties of the building. He should require a large corridor say 10 feet wide by 15 feet high, branching to the various parts of the building, and his scheme would be to use it as the channel

of air, and so to do away with all underground channels, with the exception, perhaps, of a heating chamber at the base of the tower. The air would then be passed through the channels at a velocity of $1\frac{1}{3}$ foot per second, with three channels leading to different parts of the building, taking the supply of air, as mentioned in the Paper, at 500 feet per second. If the building were heated by hot water or otherwise, so as to maintain the desired temperature independent of any change of air, any amount of air at the desired temperature could be forced through any part of the building without affecting the temperature. There might be difficulties in diffusing it so as not to make a draught, but he thought a slow current would not be any great obstacle in the corridors. There was one point in the Paper which had attracted his attention—the difference between the wet and dry bulb thermometers. He was not sure whether it was meant to maintain the same difference of temperature at 100° as was stated at 60°; but he thought it probable that a higher difference would be necessary.

Mr. SHOOLBRED said that the Author had quoted two or three common axioms, such as that "Air has a tendency to rise," "Cold air cannot rise," as "errors of judgment, based upon false notions, and leading to uncertainty and confusion." In questions of practical ventilation, there were other matters besides statements of that kind, which were in themselves correct—other natural forces coming into play, which considerably modified the mode of treating the question of the air; such as were caused by the introduction of persons into the rooms that were ventilated; the exhalations from those persons, together with the illumination of the rooms, introducing a counter-current of hot air which had a tendency to rise. According as the system of ventilation employed was downward, as in the case described, or upward, as was more generally the case, the force created by persons in the room either became an assistance in the ventilation, or an obstacle, and one requiring considerable artificial force to overcome it. The counter-current introduced in downward ventilation must not simply oppose, but be of such force and character as completely to sweep away the rising stream. That this had hardly been the result in the Glasgow University, as had been intended, was borne out by the very naïve admission made in the Paper, with reference to certain of the class-rooms. It was stated that, "in the medical and other class-rooms, which are used early in the morning, when much gas-light is required, openings for exit have been provided near the ceiling, in addition to those perforations" (the ordinary exits placed in the risers of the seats): the entrance for pure air being near the

ceiling, not very far from where the extra exits had been provided. What then might be anticipated as the result? The fresh air coming in not far from the ceiling was intended to be deflected downwards, and to pass out at the openings near the risers; but it was almost immediately subjected to the upward tendency of the heated emanations from the gas-lights towards the additional outlets; it was also affected by the heated atmosphere arising from the exhalations of the persons assembled; consequently very little of the pure air came downwards; it was sucked up by the extra openings. That view was borne out by the experiments of Professor James Thomson. By means of the smoke from burning flax or cotton, such as Dr. Reid used to employ, it was ascertained that the lower stratum of air occupied by the audience formed a nearly stagnant mass. The only action upon that mass would be the extracting influence from the ventilating shafts drawing through the outlet openings in the risers. The audience, therefore, instead of being in pure air, would be sitting in air becoming more and more vitiated every moment.

He was far from saying that downward ventilation was not applicable, and that there were not cases in which it might be fairly successful; but its difficulties were enormously increased when there were large bodies of persons to be dealt with, and particularly where the heat from the illuminants was allowed to pass freely into the room. In a room of considerable dimensions, with upward ventilation, the natural reservoir in the upper portion acted as a receptacle for the foul air, allowing it to be removed immediately from the audience. With downward ventilation, however, unless it was remarkably effective, the cold air remained at the top of the room, while the stagnant and foul air kept unfortunately below, around the persons assembled there. A short time ago he was present at the Conservatoire des Arts et Métiers, which was supposed to be the type application of General Morin's system by himself. The system of downward ventilation had been carried out there. However, he could himself state, that when, a few months ago, during the meeting of the Institution of Mechanical Engineers in the large amphitheatre of that building, he was sitting on one of the benches at some height above the floor of the room, he felt a considerable and unpleasant inward draught from the gratings in the risers, which, if there had been a downward ventilation, would have been intended as exits.

The Author had mentioned that an average allowance of 750 cubic feet per hour had been taken as the basis, in accordance with the views of "well-known authorities." The amount for

umption during the day, as stated by modern authorities, was iderably in excess of that amount. General Morin, in his exments, especially since the construction of the hospital of boissière in Paris, considered that for almost all buildings at ; 1,000 cubic feet per head per hour during the day should be wed, and for night purposes 2,000 cubic feet. Dr. Parkes coned in the latter figure; and, as far as he himself could ascer-, it appeared to be generally acknowledged as the fit and er allowance under ordinary circumstances. Dr. Reid, who probably the authority referred to, partly if not entirely, by Author, though he placed the minimum at 600 cubic feet, pro-d on some occasions a maximum of six times that amount. ventilating arrangements in the House of Commons, though y had been altered very considerably by his successor, Sir dsworthy Gurney, and also under Dr. Percy, as well as those in George's Hall at Liverpool, where Dr. Reid's original arrangeits remained much more intact, the allowance of air was much er than 600 cubic feet per head per hour.

f an allowance of 750 cubic feet per hour was not sufficient ing the day, it was wholly insufficient for night purposes; cially if gas-lights were employed and were burnt naked, as the case, if he remembered aright, in most of the class-rooms he Glasgow University. The amount of air generally acknowged to be sufficient to dilute the products of combustion was rly 2,000 cubic feet per hour per cubic foot of gas consumed, l that represented about the allowance to a single person. . Cowper had mentioned that it was worth while to place pipes ectly over the gas-jets, in order to carry off the products of nbustion. Indeed, in many large rooms where numerous naked s-jets were used, the supply of air required for the proper dilun of the gas products was in most cases equal to, and in some ore than, that necessitated by the audience in the room. It ight be interesting to the meeting to give a somewhat forcible ample on that point—the example afforded by the room in which ey were assembled. The result was so striking that it was orth mentioning. The room was 61 feet long, 39 feet broad, ith an average height of 33 feet. Its cubical contents were mewhat over 79,000 feet. It would seat, he was informed, bout three hundred and seventy-five persons closely packed. A ll attendance might be taken at three hundred. At 2,000 cubic eet each, they would consume 600,000 cubic feet of air per hour, r 7½ times the cubical contents of the room; so that in order o get that supply the room would have to be filled 7½ times

during the hour, the allowance in Glasgow being 6 times. The gas-lights were: a central sun-burner, with seven stars of eight jets each; and two side-burners, each consisting of a central eight-jet star, surrounded by a circle of twenty simple jets. The three sun-burners being placed close to the ceiling, each had its own waste pipe directly over to carry off the products of combustion, and, by the increased temperature caused around it, to aid in the ventilation of the lower part of the room. But, had all those gas-jets been left naked and distributed about different parts of the room, what would have been the case? Those one hundred and twenty burners each consumed about 3 cubic feet of gas per hour, or a total of 336 feet in an hour. Two thousand cubic feet of air to each cubic foot of gas would give 672,000 cubic feet of air—an amount exceeding that required for a full room, and more than double the amount required for an audience such as that then assembled. Of course, the amount of force of air required simply to carry off the products of combustion, not to dilute them, would be enormously less.

In connection with that subject he might mention the great advantage which the new illuminant, the electric light, possessed in that respect, since it was generally supposed to require no special supply to carry off or dilute any deleterious products of combustion; and, in regard to raising the temperature of the room itself, the advantage it afforded was even more striking. The luminous point of the electric light was very small indeed. Probably in comparison with an ordinary gas-jet, it did not present one quarter of the heating surface; and, judging from the actual result in those cases where illumination by electricity had been in regular use for several years, fifty, eighty, or perhaps one hundred gas-jets might be effectively replaced by one electric light, which would certainly give a diminished heating area of about $\frac{1}{200}$ part of that presented by the corresponding illumination by gas. So that the amelioration effected in a sanitary point of view, by electric illumination, would be considerable. The fresh air for the Glasgow University was stated to be taken from a height of 100 feet, where it was considered to be "pure" and "far from all local causes of contamination." It might be of interest to mention, that Dr. Reid took the air supply for the Houses of Parliament from a somewhat similar elevation. After being in operation for several years, doubts were thrown on the purity of this supply. Experiments upon the air taken at this elevated level, and also upon that taken from near the ground, on the river terrace, by means of intercepting screens of thin material, showed conclusively

hat the upper air was charged with a much larger proportion of oty matter, and of particles of road-dust, than it was at the lower vel. The fresh air supply at the Houses of Parliament has, herefore, for some years been taken from the latter source.

He hoped the Author would not consider that his remarks were ntended to depreciate the value of his Paper, or of his design; ecause it was evident that, from the commencement, the data of he system and the arrangements for ventilating were imposed pon him by the members of the Committee, who had no doubt arefully considered the subject beforehand.

He might be permitted, in conclusion, to mention one recent ase in which downward ventilation had been successfully applied —that of the hall of the Trocadero Palace at the recent Paris Exhibition. Hitherto it had only been used in the day. It remained to be seen how the system would act at night, when the extra heat arising from the illuminants came into play, which was specially the test of downward ventilation. During the summer months of the Exhibition every one had, however, seemed well pleased with the result. The room was calculated to seat five thousand persons, and there was an hourly allowance of upwards of 7,000,000 cubic feet of air—1,400 cubic feet per head. Both for the inlet and for the extraction of air mechanical means were used. An 8-bladed screw fan was employed in both cases, 11 feet 6 inches in diameter, and 2 feet wide. The centre of the fan was blocked off by a truncated cone. The inlet fan was driven at about ten revolutions a minute, and the exit at nine; so that there was a slight excess of pressure within the hall, such as Mr. Imray and others considered to be advantageous in excluding draughts from the outside. The speed of the air at the inlet fan was 13 feet per second; whereas at the inlet mouths in the hall it was 20 inches, and at the outlet mouths only 16 inches. The fresh air supply was a double one, and might be taken, as needed, either from above the top of the roof of the building, or from the old quarries of the Trocadero (which were now covered over and formed part of the gardens). As the mean annual temperature of the latter source was almost constant, about 54° Fahrenheit, the air taken thence might be used either to warm, or to cool, that taken directly from the external atmosphere by the upper source. The whole of the fresh air was passed to the inlet fan in the basement of the building, and previously warmed when necessary: it was thence propelled up a shaft to the top of the hall, into which it descended through a large circular central grating in the ceiling. The outlet mouths, 5,000 in number, were placed one at each sitting; but extending

high enough in the back of each seat to be above the level of ladies' dresses. Considerable care was taken in arranging the course of the outlet pipes to the exhaust fan, situated also in the basement, so that the distance from each mouth to the fan should be the same. In this way the suction draught was equalised at all the outlets. The exhaust fan propelled the foul air up a chimney to the central lantern above the hall, whence it escaped into the external atmosphere, but at a considerable distance from the high level inlet of the fresh air. The preceding particulars and explanations had been kindly given him at the building by M. Bourdais, the joint architect with M. Davioud.

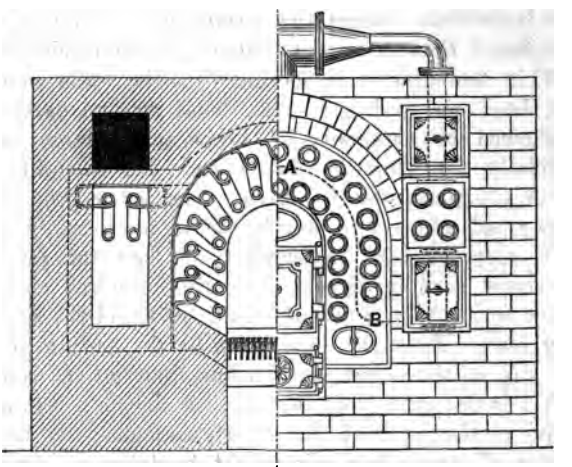
Mr. SCHÖNHEYDER remarked that, in arranging a system of ventilation such as that required for the Glasgow University, it was highly necessary to distinguish between summer and winter ventilation. In winter, warm air was needed, which should, in most cases, be supplied from above, and allowed gradually to descend, and to be abstracted at the lower part. In summer, cool air was necessary for a room where a great number of persons were assembled; and it should be in most cases supplied at the lower part of the room, and abstracted at the top, so as to allow the natural force of gravity to assist in ventilation instead of opposing it. By acting in a contrary way, there would generally be currents. If cool air were admitted at the top it would descend with a certain amount of force, and cause draughts; if warm air were admitted below, it would certainly be forced up to some extent, but portions of it would come in contact with the cooler walls, and then descend, so that the vitiated would be mixed with the fresh air, and the room, though partially, would not be successfully ventilated. Engineers differed very much upon that point, and many buildings were constructed in opposition to those suggestions. He had been obliged to ventilate rooms by an upward current where he considered a downward one would be better; and he had found that in such cases the air in certain parts of the room was not as pure, and the temperature was not as evenly distributed, as it ought to be. A good example of ventilation, on a small scale, upon the system to which he had referred, was the Galton stove. By that arrangement warm air was supplied to the upper part of the room; it was allowed gradually to descend by being cooled in contact with the walls, and it was withdrawn at the lower part of the room. It had been properly remarked by Mr. Cowper and others that ventilation by forcing air into the room was preferable in most cases If the air were obtained from a pure source, there would be a pur

supply to the room; but if the room were ventilated by suction, the air might come from an impure supply, as was the case in many private houses where there were in-draughts of impure air, causing disease and death. There need not necessarily be any complication in the system, because the downward current could be adopted in one instance, and the upward one in another. If proper channels were supplied near ceiling and floor, they might be used alternately for the supply of pure air and the withdrawal of vitiated air, by a simple arrangement of valves which might be changed. In some cases, such as for libraries, other systems had to be adopted, more warmth being required and less air. The quantity of air to be supplied varied from 500 cubic feet per person per hour to 2,000, 3,000, and in some cases 4,000 cubic feet. It was stated by different authorities that the amount of heat given out by human beings, owing to the combustion going on inside them, varied from 200 to 500 units per hour. The whole of that heat had to be carried off; and if 1,200 cubic feet of air were supplied per hour per individual, taking the specific heat of air at 0·238, it would be found that to carry it all off the air would have to be raised 23° in temperature, supposing that the walls were neither receiving heat nor giving it out. That was an excessive case, but it showed the necessity of supplying a large amount of air, especially for summer ventilation. He thought that the estimate of 500 units was too high. The screw propeller which the Author had adopted to supply air to the room was, he considered, a very wasteful instrument. It had the fault of the ordinary screw used in vessels—the slip. He had made experiments upon screw tugs, and had sometimes found the slip as much as 75 per cent. From the data given by the Author, it appeared that the slip of the screw was no less than 80 per cent., which meant that it not only propelled the air forward, but also gave it a rotary motion, and all the power consumed in that rotary motion was of course lost. It might be taken up by properly constructed guide-plates; in fact, the instrument might be improved as shown in the fan described by Mr. Cowper. Those fans were at one time made, and seemed still to be made, with casings concentric with the fan, which allowed the air to be twirled round and round before it was discharged, so that there was a great loss of power. In calculating the friction of resistance of the air channels, the Author had taken the mean of the velocities in all the pipes, the mean of the diameters, and of the circumference. That was a most extraordinary method, and the result arrived at was absurd —a resistance of only 0·04 inch, which was, of course, far too low.

Each channel should be calculated separately as to the dimensions and the velocity of the air through it.

Mr. RIVERS said that the question of what was the best hot-water boiler for an apparatus like that at the Glasgow University was one on which very different opinions had been expressed by engineers; but he believed it had been long established that the tubular principle possessed special advantages with regard to rapidity of heating. Owing, however, to the defects hitherto associated with the tubular system—the choking of the tubes, the deposition of sediment, and the defective circulation—the system had not hitherto met with the favour it deserved. Some considerable experience in the working of hot-water boilers at the Royal Gardens, Kew, had led him to make some experiments, with a view to designing a tubular boiler which should be free from those defects, and the result was shown in Figs. 3 and 4. The improved

FIG. 3.



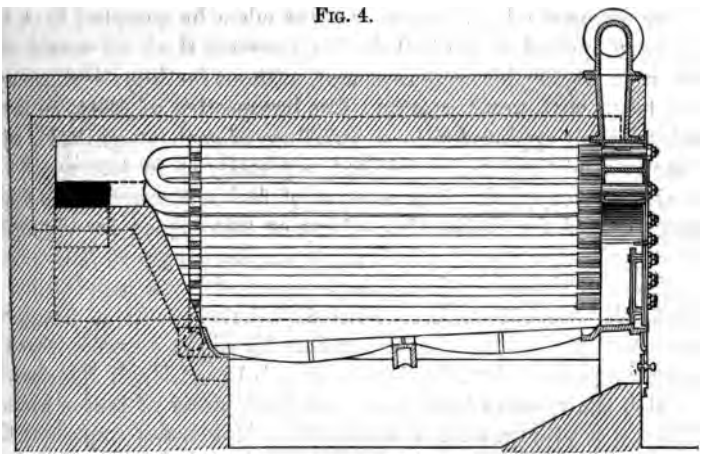

Half section. Half elevation.

The position of the diaphragm is shown by the dotted line A B.

boiler consisted of pairs of wrought-iron tubes, arranged in a horseshoe shape, and connected to a circulating chamber. The leg of each tube passed completely through the chamber, and the connection between the tube and the chamber was secured by a slotted aperture. The chamber was divided into two compartments by a diaphragm, and it would be seen that a very rapid circulation must take place in the tubes. It had been found, after the experience of a year's work, that the tubes were completely free from deposit.

One of them had been recently taken out at Kew, and it was as clean as when it was first put in. One feature of the boiler was the readiness with which repairs could be effected. Any tube could be removed by simply unscrewing a hexagon nut on the face of the chamber, and no portion of the brick seating needed removal. It had been admitted by the authorities at Kew that

FIG. 4.



Longitudinal Section.

all the defects hitherto attendant upon the tubular system had been obviated by the contrivances mentioned. Six boilers of this pattern were fixed in the palm-house at Kew, and, except in very severe weather, not more than four were in use at one time. The length of pipe heated was 19,480 feet, the area of fire-grate for four boilers was 36 square feet.

Mr. PHIPSON, in reply, said that the views expressed by Professor James Thomson were not entertained by the majority of the Professors in the University. It need not be a matter for wonder if there were some individual defects in so large a scheme, owing to the great variety of conditions. In some instances, perhaps, failures might have arisen from the means employed being inadequate to compensate for the larger number of students than was at first contemplated. He was now engaged in endeavouring to remedy these defects, and hoped, with the assistance of the Professors, to succeed in doing so. In reference to the omission of the provision for introducing the supply hot or cold, contained in Clause 5 of the Committee's instructions, he might mention that means already existed, not described in the Paper,

for passing part of the fresh air direct to the several rooms, without having to traverse the heating chambers. It might be admitted, but for the difficulty of construction, that there would be an advantage in that provision being increased in greater detail. The amount of moisture in the warm-air distributing channels, referred to by Professor James Thomson, only occurred in one part of the building. Mr. Constantine's statement of the power and action of the air warmers might be correct; but when he asserted that had they been applied to the building in question the cost would only have been £1,600, his announcement, without further details, ought to be taken with great reserve. But irrespective of that, he much doubted their application to a building of such magnitude, with so many conditions to be fulfilled, especially as to the quality of the air to be supplied. The amount of fuel consumed in an apparatus planned for the heating of one or two spaces in a compact building like the Free Trade Hall, or the Exchange at Manchester, could not be classed in the same category with an application in which the heating surfaces were distributed over a developed frontage of 1,300 feet. In illustration, he might mention that the apparatus planned by him for the Royal Albert Hall, Kensington, in which the space to be warmed, and the number of feet of heating surface, if anything, were in excess of the University apparatus, the consumption of 25 cwt. of coals per day was ample to maintain the temperature, even in severe winter weather, from 20° to 25° Fahrenheit above the external temperature, in lieu of the 45 cwt. consumed under similar circumstances in the Glasgow apparatus. Various causes had contributed to increase the annual cost of the maintenance of the application in question: the exposed position of the building, the large cooling influences of the stone walls, the numerous staircases and passages opening direct to the external air, and the subsoil of the building being clay. The temperatures of the several class-rooms quoted in the appendix did not show the maximum working power of the apparatus; they were temperatures found by experience to meet the requirements at 8 A.M. so as to ensure during the remaining portion of the day in the several class-rooms a temperature of from 57° to 60° Fahrenheit. It had also been found inexpedient to introduce a large body of persons suddenly from the external cold air into a room of which the temperature was 60° Fahrenheit, although before the hour of meeting was over it might be allowed to attain that temperature. He could not confirm all Mr. Cowper's views on the supply and extraction of the air from a ventilated space, and practice led him to believe, that unless those two elements were satisfactorily

combined, no dependence could be placed on any application for ventilation. The recent experiments on fans of different forms for ventilation lately made in France confirmed somewhat his views on that subject, since they had caused the adoption of the screw fan for the ventilating apparatus at the Trocadero Palace. There might however still be improvements in the application of motive power on the air, as had been suggested to him by having lately seen an ingenious contrivance of Professor James Thomson, by which, with the same wheel, both introduction and extraction of air might be effected. In conclusion, he might state, that in bringing that application of ventilation and warming of a large public building to the notice of the Institution, he had endeavoured to show how far, by mechanical power applied at one central point, a steady pressure, ensuring a velocity of delivery equal to from 3 to 4 feet per second, could be maintained over its entire extent.

Mr. Benjamin Verity stated, through the Secretary, that the internal mechanism of a ventilating machine devised and exhibited by him, consisted of a set of fans working in a drum, and fitted on the same axle as a flywheel. The flywheel was formed with a corrugated ridge on the outer edge, on which a fine jet or jets of water impinged, and, according to the hydraulic force, caused both wheel and fans to revolve with great velocity. The points of the axle worked in countersunk jewelled centres, and were also enclosed in metal cups containing oil for lubricating purposes, so that friction was reduced to a minimum. The water, after leaving the corrugated flywheel, was discharged across the inlet tube in the form of a shower or spray, to cleanse the incoming air before its passage through the machine. In the vertical discharge tube, also from the machine, the air was brought into contact with a coarse sponge, and was further purified previous to delivery into the room. This was particularly apparent in foggy weather, when the air pumped in was received perfectly clear. He preferred fitting the fresh air discharge-tube from the machine into the room, at about 5 feet 6 inches above the floor, and to extract the vitiated atmosphere at the ceiling. As the velocity of the fans and consequent power of the machine depended upon the amount of hydraulic pressure at command, in all cases where practicable it was advisable to derive this from the water main, or, otherwise, from a cistern placed at a suitable height. With 30 lbs. pressure, a current of air would pass through the machine at the rate of 1,000 lineal feet per minute; with increased pressure, a higher result might be obtained. In applying

the machines for warming purposes, it was proposed to generate the warm air in a room, in the lower part of a building, by a series of hot-water pipes, or by a stove. From this room it was intended to carry a galvanised iron-cased tube, packed with felt or other material to retain the heat, to the room to be warmed. This pipe, however, should be arranged to rise as much as possible, and should have separate branches to each room, with an air-propeller fitted to each outlet for exhausting the air from the warm-air tubes into the room.

The machines were separately and collectively under immediate control. This plan had been adopted at the Reform Club, and other buildings. The machine exhibited was for extracting the foul air from soil-pipes; the inner mechanism was similar to the air-propeller on a reduced scale. It was worked by a single jet of water, and its object was to create a constant upward current in the soil-pipe for the ventilation of house drains, the opening of the discharge-tube being above the roof of the building.

For the ventilation of main sewers, he recommended a machine on the exhaust principle, in the form of a stand-pipe or lamp column. In the latter case the sewer gas should be directed through the column, and should be discharged into the lantern above. This lantern, being fitted with a number of gas-burners, the sewer air, in its passage through the flame, would be deprived of its noxious properties.

---

December 10, 1878.

JOHN FREDERIC BATEMAN, F.R.SS. L. & E., President, in the Chair.

A Paper on "Railway Work in Japan," by Mr. W. Furnis Potter, M. Inst. C.E., was read at this meeting, but as the discussion could not then be taken, the publication of the Paper deferred till the next volume.

# ANNUAL GENERAL MEETING.

December 17, 1878.

JOHN FREDERIC BATEMAN, F.R.SS. L. & E., President, in the Chair.

The notice convening the meeting having been read,

Messrs. J. D. Baldry, C. Frewer, C. E. Hollingsworth, H. Law, R. C. May, T. M. Smith, J. Thomson, and A. Williams were requested to act as Scrutineers of the Ballot, for the election of the President, Vice-Presidents, and other Members of Council for the ensuing year; and it was resolved that the Ballot Papers should be sent for examination every quarter of an hour that the Ballot remained open.

The Ballot having been declared open, the Annual Report of the Council, on the Proceedings of the Institution during the past year, was read. (*Vide* page 175.)

Resolved,—That the Report of the Council be received and approved, that it be referred to the Council to be arranged for printing, and that it be circulated with the Minutes of Proceedings in the usual manner.

The Telford and Watt Medals, the Telford and Manby Premiums, the Miller Scholarship and Prizes, and the Howard Quinquennial Prize, which had been awarded, were presented. (*Vide* pages 192 and 193.)

Resolved,—That the thanks of the Institution are justly due and are presented to the Vice-Presidents and other Members of the Council, for their co-operation with the President, their constant attendance at the Meetings, and their zeal on behalf of the Institution.

Mr. Barlow, Vice-President, returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Bateman, President, for his persevering endeavours in the interests of the Institution, for his unremitting attention to the duties of his office, and for the urbanity he has at all times displayed in the Chair.

Mr. Bateman, President, returned thanks.

Resolved,—That the thanks of the Institution are due, and are

presented to Messrs. R. Price Williams and Alfred Rumball, for the comprehensive statement of Receipts and Payments they have prepared; and that Messrs. Alfred Rumball and W. B. Lewis be requested to act as Auditors for the ensuing year.

Mr. Price Williams returned thanks.

Resolved,—That the cordial thanks of the Institution be tendered to Mr. Charles Manby, the Honorary Secretary, and to Mr. James Forrest, the Secretary, for their long and valued services to the Institution.

Mr. Forrest returned thanks.

The Ballot having been open more than an hour, the Scrutineers, after examining the papers, announced that the following gentlemen were duly elected:

*President.*

JOHN FREDERIC BATEMAN, F.R.SS. L. & E.

*Vice-Presidents.*

| | |
|---|---|
| James Abernethy. | William Henry Barlow, F.R.S. |
| Sir W. G. Armstrong, C.B., F.R.S. | James Brunlees, F.R.S.E. |

*Other Members of Council.*

| | |
|---|---|
| William Baker (since deceased). | Alfred Giles, M.P. |
| Sir Joseph Wm. Bazalgette, C.B. | Harrison Hayter. |
| George Berkley. | William Pole, F.R.SS. L. & E. |
| Fred. Jos. Bramwell, F.R.S. | Robert Rawlinson, C.B. |
| George Barclay Bruce. | Charles William Siemens, F.R.S. |
| Sir John Coode. | David Stevenson, F.R.S.E. |
| William Froude, M.A., F.R.S. | Sir Jos. Whitworth, Bart., F.R.S. |

Edward Woods.

Resolved,—That the thanks of the Meeting be given to Messrs. Baldry, Frewer, Hollingsworth, Law, May, Smith, Thomson, and Williams, the Scrutineers, for the promptitude and efficiency with which they have performed the duties of their office; and that the Ballot Papers be destroyed.

# ANNUAL REPORT.

SESSION 1878-79.

terval that has elapsed since the presentation of the last Report has been fruitful of events which will undoubtedly rominent in the history of the Institution. Following the nt of recent years, the Council will review the proceedings rder given in the Bye-Laws and Regulations.

## CONSTITUTION.

he last Annual General Meeting it was resolved "that the ng Council be requested to prepare, for the consideration of al General Meeting of Members and Associates, such altera- ı the Bye-Laws as the suggestions contained in the Report ference to classification may require." The principal sug- was that in future the Institution should consist of four , namely, Senior Members or Fellows, Members, Associates, norary Members. The Council accordingly gave their care- sideration to the subject, and with legal assistance prepared ropriate scheme, which was laid before a Special General g of Members, Associates, and Honorary Members, on the November. The scheme contained such other alterations nsel advised were necessary to render the Bye-Laws con- le with the Charter. This necessity had reference mainly position in the Institution of Associates and Honorary rs, who had not previously enjoyed the full rights and pri- of chartered Members, but had been declared to be entitled h rights and privileges, according to the opinions of Sir Holker, Q.C., M.P. (Attorney-General), Sir Fitzjames Stephen, and Mr. C. Bowen, on a special case submitted to them. tion was taken to some of the proposed Bye-Laws by the g, at which it was resolved to retain the title of Member for the class, and the question was again remitted to the Council. odified set of Bye-Laws was therefore framed by Counsel, in the titles heretofore existing were retained; but it was pro- that only those future Associates who were Civil Engineers ofession should be entitled to the privileges of Corporate ership. A Special General Meeting of Members, Associates, norary Members, was summoned for the 2nd of December, to er and decide on the proposed enactments and repeals. The ed Bye-Laws were then agreed to and adopted, subject to an

amendment that present and future Civil Engineering Associates (but no others) should be designated "Associate Members," being the original recommendation of the Council, in their report to the Annual General Meeting, on the 19th of December, 1876. By the Resolution passed at the Special Meeting on the 2nd inst., this class, when fully constituted, will consist of such of the existing Associates as are Civil Engineers by profession, and of such other Associates as, at the time of their election, are engaged in some of the branches defined by the Charter as constituting the profession of a Civil Engineer.

The Council hope that the settlement thus arrived at, by the almost unanimous vote of a very full meeting, will allay any feelings of uneasiness which the long agitation of the subject may have aroused.

### Elections and Transfers.

During the past Session 95 Associates have been transferred to the class of Members, and 56 Members and 205 Associates have been elected. The deceases, resignations, and erasures together amounted to 57, leaving an effective increase of 204, or at the rate of upwards of 7 per cent. on the present number of Corporate Members. The increase in the class of Members during the last twelve months has been 136, and in the class of Associates 68, or nearly 15 and 4 per cent. respectively. There were on the register on the 30th of November last 16 Honorary Members, 1,061 Members, and 1,738 Associates—together 2,815,[1] exclusive of Students. Ten years ago the total was 1,549.

[1] The tabular statement for the years 1876–77 and 1877–78, of the transfers, elections, deceases, resignations, and erasures of the members of all classes belonging to the Institution, that is exclusive of the Students, is as follows:

| — | Session 1876–77. | | | | Session 1877–78. | | | |
|---|---|---|---|---|---|---|---|---|
| | Honorary Members. | Members. | Associates. | Totals. | Honorary Members. | Members. | Associates. | Totals. |
| Numbers on Nov. 30, 1876 and 1877 | 14 | 864 | 1,582 | 2,460 | 16 | 925 | 1,670 | 2,[illegible] |
| Transferred to Members | .. | .. | 40 | | .. | .. | 95 | |
| Elections | 2 | 46 | 169 | 217 | .. | 56 | 205 | 261 |
| Deaths | .. | 22 | 21 | | .. | 13 | 20 | |
| Resignations | .. | 2 | 15 | −66 | .. | 1 | 11 | −57 |
| Erased from Register | .. | 1 | 5 | 151 | .. | 1 | 11 | |
| Numbers on Nov. 30, 1877 and 1878 | 16 | 925 | 1,670 | 2,611 | 16 | 1,061 | 1,738 | |

The following deaths were announced during the past year, the bracketed figures after some of the names referring to the volume of "Proceedings" in which memoirs have already been printed:—

MEMBERS: George Parker Bidder, *Past-President*, Thomas Edward Dunn (liii., 282), James Graham, Sir Richard Griffith, Bart., F.R.S.E. (*post*, p. 317), James M'Nair Harkness (*post*, p. 318), Robert Jeffrey (lii., 273), Thomas Lovell, Bryce McMaster (lii., 277), Richard Stuart Norris (liv., 281), John Penn, F.R.S., William Price Struvé (lii., 278), William Fawcett Wightman, and John Thomas Woodhouse (*post*, p. 322).

ASSOCIATES: Samuel Parker Bidder (liii., 284), Henry William Ferdinand Bolckow, M.P. (*post*, p. 325), John Boyd (*post*, p. 326), Thomas Buckham (liii., 285), Charles Currey (*post*, 327), Andrew Cuthell, Captain Samuel John Dunlop, B.S.C. (liv. 283), Henry Samuel Ellis (liii., 287), John Russell Freeman (lii., 281), Edward Giles (liii. 289), Richard Hall (lii., 282), Charles William Lancaster (liii., 289), John Lean (lii., 283), Samuel Dickinson Martin (liii., 292), Thomas Boustead Nelson (liv., 284), Henry Pooley (*post*, p. 331), Alexander Clunes Sherriff, M.P. (lii., 284), William Smith, Major George Swetenham, R.E. (*post*, p. 334), and Sir Frederick Martin Williams, Bart., M.P. (*post*, p. 335).

Among those who have passed away are several whose reputations were not bounded by the profession, nor even by this country, and whose loss the Council, in common with the other members, most deeply deplore. The name of George Parker Bidder was borne on the register of the Institution for more than half a century, and for nearly half that period he was an active Member of Council, filling the Presidential Chair in the years 1860 and 1861. Few of the older members need to be reminded of the occasion when, in the early part of his friend Robert Stephenson's presidentship, Mr. Bidder delivered a lecture on "Mental Calculation,"[1]—his first and only attempt to expound and explain the great gift with which he was endowed—or of the interest elicited by what was virtually the story of his life. Mr. Bidder was for many years a most regular attendant at the meetings, and invariably took part in all important debates, his keen intellect and powerful oratory tending greatly to advance the discussions.

Another veteran member was Mr. John Penn, who was elected as far back as 1824, and who likewise served on the Council for some years. Though not so intimately connected with the history of the Institution as was Mr. Bidder, his name may have even

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xv., p. 251.

been better known to the public from his inventions and improvements in connection with the marine steam-engine. In the large establishment founded by his family, the chief aim was to stimulate the mechanic to take a pride in his labour, and to be satisfied with nothing but the best and most conscientious workmanship.

Mention, too, may fitly be made of Mr. Bolckow, M.P., as one who materially added to the resources of the country, by the active part he took in the opening up of the Cleveland iron-stone district.

The resignations have been accepted of James Deas, *Member*, and of John Berry Clacy, Gabriel Gordon Cleather, Henry Halford Coventry, Samuel Gale, George Rushout Godson, Lieut.-Col. William Robert Houghton, Samuel Lack Mason, Edward Pritchard, Arthur Ricketts, Alfred Ayscough Wilkinson, and Sir William Wright, *Associates*.

### Admission of Students.

The Council have admitted 142 Students during the past session, while 56 were elected Associates, and 34 ceased to remain on the lists, so that the net increase has been 52. Since the establishment of this class on the 19th of November, 1867, the number of candidates admitted has been 965, of whom 500½ are still on the list of Students, 254 have been elected Associates, and 211 are no longer attached to the Institution.

### Contributions to the Funds.

The number of Residents and of Non-Residents in the various classes—those being still included in the latter category who reside beyond ten miles from the General Post-Office—and the gross amounts of Annual Subscriptions for 1878 actually obtained, as shown in the Abstract of receipts and payments, are given in the following statement:

| Class. | Residents. | Non-Residents. | Totals. | Subscriptions. |
|---|---|---|---|---|
| | | | | £. s. d. |
| Members . . . | 356 | 705 | 1,061 | 3,267 12 0 |
| Associates . . . | 652 | 1,086 | 1,738 | 4,531 5 6 |
| Honorary Members | 9 | 7 | 16 | 0 0 0 |
| Students . . . | 186 | 314 | 500 | 820 11 6 |
| Totals . . . | 1,203 | 2,112 | 3,315 | 8,619 9 0 |

Of the Members 32 residents and 55 non-residents have compounded for future Annual Subscriptions, and of the Associates 4 residents and 50 non-residents have similarly compounded.

The Subscriptions remaining in arrear on the 30th of November ast were as under:

| Class. | Residents. | Non-Residents. | Totals. | Arrears. |
|---|---|---|---|---|
| | | | | £. s. d. |
| Members . . . | 8 | 27 | 35 | 121 16 0 |
| Associates . . . | 39 | 35 | 74 | 217 7 0 |
| Students . . . | 16 | 13 | 29 | 54 1 6 |
| Totals . . . | 63 | 75 | 138 | 393 4 6 |

## Balloting List for Council.

In preparing the balloting list for the present meeting, the Council have advisedly selected names from the Member class only, since the future non-professional Associates, from which class the Associate Members of Council have hitherto been chosen, will not be entitled to the privileges of Corporate Membership, and will therefore be ineligible.

## Meetings and Publications.

Exclusive of the evening on which the President delivered his inaugural address, twenty-three Ordinary Meetings have been held, at which 15 Original Communications were read and discussed. The subjects included most of the matters mentioned in the Charter as coming within the scope of the Civil Engineer's art. It may however be noticed, as an instance of the changes that occur in the relative prominence of various branches of the profession, that, while "the art of navigation by artificial power for the purposes of commerce" is one of the last items mentioned in Smeaton's definition, roads and canals being the first, their positions have been so far reversed, that a Paper on Steam Navigation, with discussion, occupied four evenings of the Session; while there has been no memoir relating in any way to canals for the last twenty years; and the subject of inland roads, as regards this country, seems to have dropped out of notice. This is to be regretted, as for many years great attention has been devoted to road-making in countries where there is a large, heavy, and rapid traffic; a subject

upon which a most useful Paper might be written, and much valuable information might be elicited by its discussion.

It is a matter for congratulation that the attendances at the Ordinary Meetings show a steady and continual increase. The average last Session was 274, which is the highest yet attained. As a general rule, apart from the influence of the weather or other temporary causes, the attendance is most numerous at the beginning of the Session, and then steadily declines, until the number of those present at the later meetings barely reaches two-thirds that at the earlier ones. Thus, the average number present at three meetings in November 1877 was 347, while in the following May the average was only 236.

In addition to the Original Communications read and discussed at the meetings, 22 Other Selected Papers have been printed in the "Minutes of Proceedings." All of these merit careful study, and have been considered by the Council in the award of Premiums.

The Authors of 7 out of the 15 Papers read at the Ordinary Meetings have had awarded to them the following Premiums: viz., Telford Medals and Telford Premiums to Richard William Henry Paget Higgs, Ph.D., and John Richard Brittle, and Thomas Curtis Clarke; Watt Medals and Telford Premiums to Henry Davey, Bradford Leslie,[1] and Alfred Holt; a Telford Premium to James Atkinson Longridge,[2] and the Manby Premium to Edward Bazalgette. For 5 out of the 22 Papers printed in the "Proceedings" without being discussed, Telford Premiums have been adjudged to William Cawthorne Unwin,[2] B. Sc., John Lewis Felix Target, George Wilson, Frederick Cadogan Barron, and William Carson. A detailed list of these awards will be found in the Appendix to this Report.

The First Howard Quinquennial Prize, being that for the year 1877, has been awarded to Mr. Henry Bessemer, as—in terms of the bequest—the inventor of a new and valuable process relating to the uses and properties of iron.

It is not necessary to refer more particularly to any of the Papers, as they have been for some time before the members in the four volumes of "Minutes of Proceedings," which were issued somewhat earlier than usual. These volumes together contain 1609 pages of letter-press, illustrated by 39 plates and numerous woodcuts. The printed matter under Sect. I., "Minutes of Proceedings,"

[1] Has previously received a Telford Medal.

[2] Has previously received both Telford and Watt Medals.

amounts to 814 pages; under Sect. II., "Other Selected Papers," and Memoirs of Deceased Members, to 328 pages; and under Sect. III., "Abstracts of Papers in Foreign Transactions and Periodicals," to 467 pages; the last section having been continued on the same scale as in preceding years.

In future volumes of the "Minutes of Proceedings" there will be given, from time to time, short reports of the progress of different branches of Engineering abroad, as shown by the Abstracts. Since the publication of the foreign abstracts was commenced, four years ago, there has been great development in many departments of the profession abroad. These progress-reports will bring prominently before English engineers the advances that have been made by their brethren in foreign countries; and the Council have been induced to give so much prominence to the records of foreign engineering, in the hope that they will command serious attention, especially from the younger members.

The General Index to the first fifty volumes of the "Minutes of Proceedings," including also the three volumes of quarto "Transactions," is in the press, and will shortly be issued. The great mass of matter contained in the volumes to which it refers has rendered necessary a departure from the plan followed in the compilation of the general indexes for the series of volumes from I. to XX., and from XXI. to XXX. The present Index will be limited to an alphabetical list of the subjects of every Paper published by the Institution up to the end of the year 1877, with the names of the respective Authors, and of such cross references as have been deemed expedient, both to the special subjects of the different articles and to the subjects discussed, with, in the latter case, the names of the speakers. A "Name Register" of Authors, and of others included in the Index, will be added as a supplement. A glance through this catalogue will afford a good idea of the value of the labours of the Institution in the collection and diffusion of engineering knowledge, and will prove that it has nothing to fear from a comparison between its work and that of any similar scientific body.

Supplemental Meetings for Students were held on ten Friday evenings, on each of which a Member of Council presided, and a Paper was read and discussed. It is a matter of gratification to the Council that they have been again able to award the Miller Scholarship of £40 per annum tenable for three years. On this occasion it has been bestowed on William Bell Dawson, who had previously distinguished himself at the McGill University, Montreal, and at the Ecole des Ponts et Chaussées, Paris, for his

Paper on "The Eastern Canal of France." This memoir will b printed as a Selected Paper in the next volume of the Proceeding It is specially recommended to the Students as a communicatio of a character most useful and desirable for them, viz., a clearl written and well illustrated account of a work of magnitude, in th present case referring to a branch of engineering in which the Frenc have long been pre-eminent. The Students' Papers generally hav been of fair merit and promise, and for four of the others Mill Prizes have been given to Percy Wilson Britton, Arthur Camero Hurtzig, Arthur Spence Moss, and Alfred Weeks Szlumper. Th average attendance at these meetings was 22. The largest numb of Students present on one occasion was 39, the smallest number, Last year, as formerly, there was a marked diminution in th numbers present at the later meetings, the average attendanc having been 27 at the first five meetings, as against 17 at th last five.

The visits of Students to works in progress have been continue during the past year, and the Council have to acknowledge th courtesy of Messrs. Lucas and Aird in respect of their invitati to the Victoria Docks Extension Works; of the Chartered G Company, for affording facilities for inspecting their great wor at Beckton; of the Thames Ironworks and Shipbuilding Compa for like permission to visit their establishment at Canning Tow as also of Sir J. Bazalgette and Mr. Alfred Williams, and of t Burham Brick, Lime, and Cement Company, in regard to the W Kent Sewerage Works and the Burham Works respectively. T thanks of the Council have likewise been tendered to Mr. Edw M. Barry, R.A., for so kindly placing tickets for his course lectures "On Architecture" at the Royal Academy at the d position of every Student of the Institution.

## MEETINGS OF OTHER SOCIETIES.

The Council have had much pleasure in continuing to grant t use of the rooms to the Institution of Mechanical Engineers, t Iron and Steel Institute, the Meteorological Society, and t Society of Telegraph Engineers, for their several meetings; also, on occasions, to the Sanitary Institute of Great Britain, a to the Council of the Association of Municipal Engineers a Surveyors.

## Paris Exhibition of 1878.

When the International Jury, in Group 6, Class 66, was engaged in its labours, surprise was expressed that The Institution of Civil Engineers was not officially represented as were some other societies. Mr. G. R. Redgrave was deputed by the Royal Commission to ascertain whether, even at that late period, an exhibit could be arranged. Under these circumstances a selection was hastily made of drawings, diagrams, and photographs, by various members of the Institution, and of others which happened to be in the possession of the Institution—representing some of the more notable modern engineering works,—supplemented by a set of the "Minutes of Proceedings." This collection, on being submitted to the Jury, led to the award to the Institution of a Diploma of Honour.

While on the subject of the Paris Exhibition, the Council cannot refrain from expressing, on behalf of the Institution, and of the British Engineering profession generally, a sense of the courtesies afforded by their brethren in Paris. To M. Tresca thanks are especially due, for he, as President of "the Société des Ingénieurs-civils," offered, on behalf of that Society, to grant the use of their rooms and Library to the Institution, and generally all other facilities in their power to any member visiting the Exhibition. The Council wish also to acknowledge very cordially the kindness and assistance rendered by those French Engineers and Chiefs of Departments to whom the Secretary of the Institution addressed letters of introduction on behalf of individual members.

## The Library.

The Library possesses the advantage that it was founded when no other collection of books of the same kind was in existence. It consequently contains a large number of scarce, valuable, and costly works, both English and foreign, which were in the first instance willingly contributed to the Institution as the only public professional repository, and the presentation of such works has since been continued. This rich and unparalleled collection of engineering literature could never be replaced, and it is believed that no standard work of professional interest is long absent from the collection. It has been the constant care of successive Councils to maintain its character and completeness. As a matter of fact this is a work of increasing difficulty, owing to the greater development of literary activity of late

years, especially on the continent. As a means to this end, when any subject is brought before the Institution, or an inquiry is made, the Officers invariably endeavour to ascertain the titles of any treatises, reports, or pamphlets, bearing on the question, in which the Library may be deficient, with a view to their being obtained. The accumulation of tracts, bound up in three hundred 8vo, eighty-three 4to, and twenty-five folio volumes, is a notable feature of the Library. Each volume on an average contains fifteen pamphlets, some of them dating from the sixteenth century, and affording much curious information on questions of the day, which from their ephemeral nature are not referred to in more ambitious treatises. During the past year the presentations, exchanges, and purchases have suffered no diminution. The list of donors, contained in an Appendix to this Report, will indicate those individuals and societies to which the Institution is indebted. Special mention may, however, appropriately be made of the presentation by the Institution of Mechanical Engineers, of forty volumes of the "Bulletin de la Société Industrielle de Mulhouse," and by Sir Joseph Bazalgette, Member of Council, of copies of the specifications and contract drawings relating to the Thames Embankment, in continuation of the Main Drainage drawings received from him.

The last subject-matter Catalogue of the Library was printed in 1870. This has been supplemented in manuscript down to the present date, and will be so continued. In compliance with a suggestion made some time since, all new works, not being continuations of periodicals, are laid on the table for some weeks before being placed on the shelves.

It continues to be a matter for regret, that greater use is not made of the Library; at the same time, the Council are gratified to find, that the number of visitors increases in proportion to the growth of the Institution. The Council hope that as a knowledge of the advantages of the Library becomes more diffused, so will its usefulness to the student be better appreciated.

## The Property of the Institution.

If the several items which make up the credit side of the financial statement for the year 1877–78 are grouped under their three principal headings, it will be found that the income proper—that is, the annual subscriptions and dividends—amounted to £10,610 0*s.* 6*d.*; the additions to capital, consisting of life compositions, admission and Building fund fees, to £2,984 19*s.*; and the

dividends on investments under trust, to £461 3*s*. 1*d*. These three sums, together with various balances not being receipts during the present year, amounting to £355 18*s*. 6*d*., make the total of £14,412 1*s*. 1*d*., representing the gross revenue to be accounted for. It will be noted with satisfaction that £1,072 10*s*. 4*d*., or rather more than a tenth of the income, proceeds from invested property.

The expenditure has been, for House and establishment charges, £4,985 10*s*. 3*d*.; for Minutes of Proceedings, £4,953 8*s*. 4*d*.; and for premiums and prizes under trust, £387 5*s*. 2*d*.; together, £10,326 3*s*. 9*d*. To this must be added, to effect a balance, the purchase money of £3,000 Caledonian Railway Debenture Stock, viz., £3,135 14*s*. 2*d*.; a sum of £21 2*s*. 4*d*. due from the Benevolent Fund for petty disbursements; and cash in the hands of the Treasurer on the 30th of November, £929 0*s*. 10*d*.

In the last report it was stated that a balance of £726 7*s*. 6*d*. was due from income to capital. By an investment of double the nominal value of that made in 1877, the Council have been enabled to cover the full amount due to capital for 1878, and at the same time to reduce the liability referred to by a sum of £150 15*s*. 2*d*.; it is therefore now only £575 12*s*. 4*d*. There is also an indebtedness to the Telford and the Miller Trust Funds of £48 8*s*. 1*d*., and of £58 12*s*. 4*d*., respectively, being the balances on the last two years' transactions.

In regard to the expenditure on account of Minutes of Proceedings, the Council would remark that five volumes have been paid for in 1878. They have thus complied with the recommendation of their predecessors, to complete the payment for all publications already issued. It may therefore be reasonably expected, that in future the disbursements of each year will be met by the income of that particular year. In round numbers, the edition of each volume costs rather more than £1,000. This is for 3,750 copies, besides about 250 reprints of all articles—practically, therefore, 4,000 copies of each volume—and includes the cost of distribution to members, both at home and abroad, the private press abstracts, the shorthand writers' notes, assistance in preparing the foreign abstracts, and indeed, every payment connected with the publications.

The large increase observable under the head of Rates and Taxes is owing to the payment of £171 12*s*. 5*d*. to the parishes of St. Margaret and St. John the Evangelist, Westminster, who put in a distress for parochial rates for 1877, notwithstanding that the Institution has, under the 6th and 7th Vict., chap. xxxvi., enjoyed exemption from county, borough, parochial and other local rates,

ever since that Act became operative. A written protest against this distress was handed to the parties making it, on the ground of its being illegal, because of the Act above referred to, and unwarranted, because the Institution had always been ready to agree to try the matter in a superior court, while the parochial authorities had not thought proper to meet the case in that way. The Institution has appealed against the rate, and the case was down for trial at the October sessions, when it was adjourned until January.

It may be remembered that there was the option of purchasing the premises in the occupation of the Institution up to Midsummer, 1878. The Council, acting in your interest, have not deemed it advisable to exercise this power. There now remain 88½ years unexpired of the period for which the premises are held on lease.

The nominal or par value of the investments, representing the accumulated property of the Institution and the Trust Funds, is now £41,500 6*s*. 2*d*., as against £38,450 6*s*. 2*d*. at the same time last year. The Great Eastern Railway Company having converted their Norfolk Five per Cent. Preference Stock into Perpetual Four per Cent. Debenture Stock, the Manby Donation is now represented by £250 of the latter instead of £200 of the former stock.

Of the investments a sum of £12,500 6*s*. 2*d*. is placed in Government stocks, and the balance in Four or Four and a half per Cent. Debenture stocks of nine of the principal railway companies, in nearly equal proportions. It is gratifying to note that the Debenture stocks have improved in value since the earlier investments were made, so that at the present time they are worth rather more than £30,200, the original purchase money having been £29,401 12*s*. 6*d*.

## Conclusion.

The Council have pleasure in stating that the progress of the Institution during the past twelve months has been not less satisfactory than in former years. This is the more gratifying when it is considered that there has been a wide-spread and deep-rooted financial depression for so long a period, and that the well-being of the Institution is largely dependent on the prosperity of the country. The anxiety of engineers to be enrolled on the register of the Institution may be taken as evidence of the esteem in which it is held.

# RECEIPTS AND EXPENDITURE.

## ABSTRACT *of* RECEIPTS *and* EXPEND

### RECEIPTS.

| *Dr.* | £. | s. | d. | | |
|---|---|---|---|---|---|
| To Balance in the hands of the Treasurer . . . . | 309 | 11 | 5 | | |
| — „ „ „ Secretary . . . . | 13 | 7 | 4 | | |
| | | | | | 3 |
| — Subscriptions and Fees:— | | | | | |
| Arrears . . . . . | 294 | 0 | 0 | | |
| Current . . . . . | 8,619 | 9 | 0 | | |
| Advance . . . . . | 113 | 2 | 6 | | |
| Life Compositions . . . . . | 620 | 7 | 0 | | |
| Admission Fees . . . . . | 819 | 0 | 0 | | |
| | | | | | 10,4 |
| — Building Fund . . . . . | | | | | 1,5 |
| — Publication Fund . . . . . | | | | | 3 |
| — Library Fund . . . . . | | | | | |
| — Minutes of Proceedings:—Repayment for Author's separate copies, &c. . . . . | | | | | |

— Dividends: 1 year on TRUST FUNDS.

| £. | s. | d. | | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Telford Fund.* | | | | |
| 2,839 | 10 | 10 | Three per Cent. Consols. . . | 83 | 15 | 3 | |
| 2,586 | 0 | 11 | Three per Cent. Reduced . . | 76 | 5 | 8 | |
| 2,377 | 10 | 5 | Three per Cent. Consols (Unexpended Dividends) . . | 70 | 2 | 10 | |
| 862 | 14 | 5 | Three per Cent. Reduced (Ditto, ditto) . . . . . | 25 | 9 | 2 | |
| 8,665 | 16 | 7 | Total nominal or par value. | | | | 2 |
| | | | *Manby Donation.* | | | | |
| 250 | 0 | 0 | Great Eastern Railway Co., Four per Cent. Debenture Stock. | .. | | | |
| | | | *Miller Fund.* | | | | |
| 2,000 | 0 | 0 | Lancashire and Yorkshire Railway Four per Cent. Debenture Stock . . . . . | 78 | 16 | 8 | |
| 1,100 | 0 | 0 | Great Eastern Ditto . . . . | 43 | 7 | 3 | |
| 582 | 18 | 6 | Three per Cent. Consols (Unexpended Dividends) . . . | 17 | 3 | 11 | |
| 1,355 | 14 | 11 | Three per Cent. Reduced (Ditto, ditto) . . . . . | 39 | 19 | 10 | |
| 5,038 | 13 | 5 | Total nominal or par value. | | | | 1 |
| | | | *Howard Bequest.* | | | | |
| 551 | 14 | 6 | New Three per Cents. . . . | .. | | | |
| | | | INSTITUTION INVESTMENTS. | | | | |
| 3,650 | 0 | 0 | Great Eastern Railway Four per Cent. Debenture Stock . . | 143 | 17 | 9 | |
| 3,000 | 0 | 0 | London and North Western Ditto . . . . . | 118 | 5 | 0 | |
| 1,500 | 0 | 0 | London, Brighton, and South Coast Ditto . . . . . | 59 | 2 | 6 | |
| £8,150 | 0 | 0 | Carried forward . . | £321 | 5 | 3 | £13,2 |

1st DEC., 1877, *to the* 30th NOV., 1878.

PAYMENTS.

| | £. s. d. | £. s. d. |
|---|---|---|
| e, Great George Street, for Rent, &c.:— | | |
| Repairs | 129 11 1 | |
| Rent | 649 13 10 | |
| Rates and Taxes | 236 8 6 | |
| Insurance | 42 0 11 | |
| Furniture | 13 1 0 | |
| | | 1,070 15 4 |
| es | | 1,812 10 0 |
| , Messengers, and Housekeeper | | 606 12 0 |
| ion to late Housekeeper | | 30 0 0 |
| ge and Parcels:— | | |
| Postage | 132 9 2 | |
| Parcels | 4 10 2 | |
| | | 136 19 4 |
| nery, Engraving, Printing Cards, Circulars, &c. | | 441 8 10 |
| , Fuel, &c.:— | | |
| Coal and coke | 45 16 0 | |
| Candles | 0 2 1 | |
| Oil | 0 14 0 | |
| Gas | 64 14 4 | |
| Water for engine | 5 8 0 | |
| | | 116 14 5 |
| nd Coffee | | 39 13 7 |
| ry:— | | |
| Books | 261 10 11 | |
| Periodicals | 58 18 9 | |
| Binding | 83 14 8 | |
| | | 404 4 4 |
| cation, "Minutes of Proceedings" | | 4,953 8 4 |
| rd Premiums | | 145 17 8 |
| Medals | | 4 15 0 |
| y Premium | | 9 19 9 |
| r Scholarships | | 80 0 0 |
| r Prizes | | 64 16 3 |
| rd Prize | | 81 16 6 |
| mas | | 31 4 4 |
| al Dinner (Official Invitations, &c.) | | 119 12 1 |
| ling and Repairing Clocks | | 2 6 6 |
| ental Expenses:— | | |
| Christmas Gifts | 2 9 0 | |
| Assistance at Ordinary Meetings | 11 15 6 | |
| Ditto at Students' Meetings | 3 15 0 | |
| Beating Carpets and Sweeping Chimneys | 16 2 6 | |
| Household Utensils, Repairs, and Expenses | 105 4 10 | |
| | | 139 6 10 |
| al Expenses | | 34 2 8 |
| Carried forward | | £10,326 3 9 |

## ABSTRACT *of* RECEIPTS *and* EXPENDITURE

RECEIPTS—*cont.*

| *Dr.* £. | s. | d. | | £. | s. | d. | £. | s. | d. |
|---|---|---|---|---|---|---|---|---|---|
| 8,150 | 0 | 0 | Brought forward . . | 321 | 5 | 3 | 13,286 | 17 | 8 |
| | | | To Dividends—*cont.* | | | | | | |
| | | | INSTITUTION INVESTMENTS: *cont.* | | | | | | |
| 3,000 | 0 | 0 | North Eastern Railway Four per Cent. Debenture Stock. | 118 | 5 | 0 | | | |
| 3,000 | 0 | 0 | Great Northern Ditto . . . | 118 | 5 | 0 | | | |
| 1,000 | 0 | 0 | Lancashire and Yorkshire Ditto . . . . . | 39 | 8 | 4 | | | |
| 3,000 | 0 | 0 | Great Western Ditto . . . | 118 | 5 | 0 | | | |
| 3,000 | 0 | 0 | Caledonian Ditto . . . . | 117 | 17 | 6 | | | |
| 1,500 | 0 | 0 | London, Brighton, and South Coast Ditto, Four and a Half per Cent. Ditto . . | 66 | 10 | 4 | | | |
| 3,000 | 0 | 0 | Manchester, Sheffield, and Lincolnshire Ditto . . . . | 133 | 0 | 11 | | | |
| 1,344 | 1 | 8 | New Three per Cents . . . | 39 | 13 | 0 | | | |
| £26,994 | 1 | 8 | Total nominal or par value . . | | | | 1,072 | 10 | 4 |
| To Interest on Deposit account . . . . . | | | | | | | 19 | 13 | 4 |
| | | | | | | | £14,379 | 1 | 4 |
| — Benevolent Fund Petty Disbursements, 1877 . . . . . | | | | | | | 18 | 14 | 8 |
| — Balance of Petty Cash due to the Secretary . . . . . | | | | | | | 14 | 5 | 1 |
| | | | | | | | £14,412 | 1 | 1 |

SUMMARY OF INVESTMENTS.

| | | | | |
|---|---|---|---|---|
| TRUST FUNDS— | | | | |
| Telford Fund . . . . . | 8,665 | 16 | 7 | |
| Manby Donation . . . . . | 250 | 0 | 0 | |
| Miller Fund . . . . . | 5,038 | 13 | 5 | |
| Howard Bequest . . . . . | 551 | 14 | 6 | |
| | | | | 14,506 4 6 |
| INSTITUTION INVESTMENTS . . . . . | | | | 26,994 1 8 |
| | | | | £41,500 6 2 |

*m the* 1ST DEC., 1877, *to the* 30TH NOV., 1878.

PAYMENTS—*cont.*

| *Cr.* | | £. | *s.* | *d* |
|---|---|---|---|---|
| Brought forward . . . . . | | 10,326 | 3 | 9 |
| Benevolent Fund Petty Disbursements, 1878 . . . . . | | 21 | 2 | 4 |
| Institution Investment :— | | | | |
| £3,000 Caledonian Railway Four per Cent. Debenture Stock . . . . . | .. | 3,135 | 14 | 2 |
| Balance Nov. 30, 1878, in the hands of the Treasurer . . . . . | .. | 929 | 0 | 10 |
| | | £14,412 | 1 | 1 |

Examined and found correct.

(Signed) R. PRICE WILLIAMS, ALFRED RUMBALL } *Auditors.*

AMES FORREST, *Secretary.*

*December 6th*, 1878.

## PREMIUMS AWARDED.

### SESSION 1877–78.

THE COUNCIL of The Institution of Civil Engineers have awarded the following Premiums:

FOR PAPERS READ AT THE ORDINARY MEETINGS.

1. Telford Medals, and Telford Premiums, to Richard William Henry Paget Higgs, LL.D., Assoc. Inst. C.E., and John Richard Brittle, Assoc. Inst. C.E., for their Paper on "Some Recent Improvements in Dynamo-Electric Apparatus."
2. A Watt Medal, and a Telford Premium, to Henry Davey, M. Inst. C.E., for his Paper on "Direct-acting or Non-rotative Pumping Engines and Pumps."
3. A Telford Medal, and a Telford Premium, to Thomas Curtis Clarke, M. Inst. C.E., for his Paper on "The Design generally of Iron Bridges of very large Span for Railway Traffic."
4. A Watt Medal, and a Telford Premium, to Bradford Leslie, M. Inst. C.E., for his Paper on "The Hooghly Floating Bridge."
5. A Telford Premium, to James Atkinson Longridge,[2] M. Inst. C.E., for his Paper on "The Evaporative Power of Locomotive Boilers."
6. A Watt Medal, and a Telford Premium, to Alfred Holt, M. Inst. C.E., for his "Review of the Progress of Steam Shipping during the last Quarter of a Century."
7. The Manby Premium to Edward Bazalgette, Assoc. Inst. C.E., for his Paper on "The Victoria, Albert, and Chelsea Embankments of the River Thames."

FOR PAPERS PRINTED IN THE PROCEEDINGS WITHOUT BEING DISCUSSED.

1. A Telford Premium to William Cawthorne Unwin,[2] B.Sc., M. Inst. C.E., for his Paper on "The Centrifugal Pump—

[1] Has previously received a Telford Medal.
[2] Has previously received both Telford and Watt Medals.

2. A Telford Premium to John Lewis Felix Target, Assoc. Inst. C.E., for his Paper on "The Main Drainage of Paris, and the Utilisation of its Sewage."

3. A Telford Premium to George Wilson, M. Inst. C.E., for his Paper on "Irrigation in the South of France; Department of the 'Bouches-du-Rhône.'"

4. A Telford Premium to Frederick Cadogan Barron, M. Inst. C.E., for his Paper on "The Works of the Bilbao Iron Ore Company in the Province of Biscay, Spain."

5. A Telford Premium to William Carson, M. Inst. C.E., for his Paper on "The Egremont Ferry Landing."

FOR PAPERS READ AT THE SUPPLEMENTAL MEETINGS OF STUDENTS.

1. The Miller Scholarship to William Bell Dawson, B.A., Stud. Inst. C.E., for his Paper on "The Eastern Canal of France, for establishing a Line of Water Communication from the Saône to the Meuse."

2. A Miller Prize to Percy Wilson Britton, Stud. Inst. C.E., for his Paper on "The Construction of Plate-Girder Bridges."

3. A Miller Prize to Arthur Cameron Hurtzig,[1] Stud. Inst. C.E., for his Paper on "Some Formulæ for Pile Driving."

4. A Miller Prize to Arthur Spence Moss,[1] Stud. Inst. C.E., for his Paper on "Two Miles of Bridge Foundations, or Foundation Works at the Tay Bridge."

5. A Miller Prize to Alfred Weeks Szlumper, Stud. Inst. C.E., for his Paper on "Lead Mining, and the Washing and Dressing of the Ores of Lead, Copper, Tin, and Zinc, and the Smelting of the same."

The HOWARD QUINQUENNIAL PRIZE for 1877 to Henry Bessemer, M. Inst. C.E., as—in terms of the bequest—the inventor of a new and valuable process relating to the uses and properties of iron.

[1] Has previously received a Miller Prize.

## SUBJECTS FOR PAPERS.

### Session 1878–79.

The Council of The Institution of Civil Engineers invite communications, of a complete and comprehensive character, on any o the Subjects included in the following list, as well as on othe analogous questions. For approved Original Communications the Council will be prepared to award Premiums, arising out o special Funds bequeathed for the purpose, the particulars o which are as under :—

1. The Telford Fund, left "in trust, the Interest to be ex pended in Annual Premiums, under the direction of the Council.' This bequest (with accumulations of dividends) now produce about £260 annually.

2. The Manby Donation, producing about £10 a year, given "t form a Fund for an Annual Premium or Premiums for Papers rea at the meetings."

3. The Miller Fund, bequeathed by the testator "for the pur pose of forming a Fund for providing Premiums or Prizes for the Students of the said Institution, upon the principle of the 'Telford Fund.'" This Fund (with accumulations of dividends) now realises nearly £180 per annum. Out of this Fund the Council have established a Scholarship,—called "The Miller Scholarship of Th Institution of Civil Engineers,"—and are prepared to award on such Scholarship, not exceeding £40 in value, each year, an tenable for three years.

4. The Howard Bequest, directed by the testator to be applie "for the purpose of presenting periodically a Prize or Medal t the author of a treatise on any of the uses or properties of iron, o to the inventor of some new and valuable process relating thereto such author or inventor being a Member, Graduate, or Associate of the said Institution." The annual income amounts to rather more than £16. It has been arranged to award this prize every five years, commencing from 1877. The next award will therefore be made in 1882.

The Council will not, in any case, make an award unless a communication of adequate merit is received; but, on the other

hand, more than one Premium will be given, if there are several deserving memoirs on the same subject. In the adjudication of the Premiums no distinction will be made between essays received from a Member, an Associate, or a Student of the Institution (except in the cases of the Miller and the Howard bequests, which are limited by the donors), or from any other person, whether a Native or a Foreigner.

LIST.

1. The Triangulation Survey, and Mapping of Countries and Districts, including the Astronomical Observations required for latitude and longitude, and the measurement of bases; with a description of the instruments employed, the reduction of the observations, and degree of accuracy of the results.
2. The Levelling of Countries, either by spirit-levelling, vertical angles, barometers, or the boiling-point of water; with a description of the instruments employed, the reduction of the observations, and degree of accuracy of the results.
3. The effect of the lapse of time on the Strength of Materials strained beyond the supposed limit of elasticity, but within the ultimate strength.
4. The Stresses inducing the failure of Iron Ships, as bearing on the probable endurance of large iron structures under high strains and repeated bendings.
5. The Causes of Slips in Rocks and Earths of different kinds, and the Conditions that induce treacherous ground in Railway-cuttings, tunnels, and the sides of valleys near reservoir banks.
6. The best combined system of Warming, Ventilating, and Lighting large Buildings.
7. The most suitable materials for, and the different systems of, Road-making for large Towns, where the traffic is heavy, including a Comparison of First Cost, Maintenance, and Durability.
8. The Construction of Iron Piers for Viaducts, with practical examples of French, American, and other systems.
9. The Design and Construction of a Steel Bridge, with particulars of the weight and cost, and of the tests to which it has been subjected, compared with an iron bridge of the same span.
10. The Works carried out on the Continent of Europe for the Improvement of Rivers, and of Inland Navigation generally.
11. The Design and Construction of Movable Weirs across Rivers.

12. The Treatment of Estuaries, with special reference to tida capacity.
13. The Design and Construction of Dock Gates and Caissons including the requisite external and internal arrangements illustrated by recent practical examples.
14. The Design and Construction of Building-slips for large Vessels.
15. The Construction of Tide Gauges, and the usual method of carrying out a systematic series of Tidal Observations.
16. The Storage and Filtration of Water, both natural and artificial, and the arrangements for the distribution of water in towns.
17. The systems of Domestic Water Supply suitable for rainless districts.
18. The benefits and expedients of Irrigation in India and in other warm climates, and the proper construction of Irrigating Canals, so as to avoid erosion or silting, and to prevent the growth of weeds.
19. The Bearing of Recent Experiments on the Resistance of Vessels, and on Skin Friction upon other Hydraulic Problems.
20. The most recent Types of Iron Sleepers for Railways, with practical results and statistics.
21. The best practical Use of Steam in Steam Engines, and the effects of the various modes of producing Condensation, and of various grades of expansion.
22. Compressed Air as a Motive Power, particularly as applied to Machinery in Mines and for traction on Tramways and in Tunnels.
23. The Relative Advantages of Steam, Heated Air, Gas, Water and Electricity as the Motive Power in small Engines.
24. Wind and Water as Motive Powers, compared with Steam Power, and the Motors most suitable for utilising them.
25. The differences in design of British and Foreign Locomotive Engines; showing the benefits derived from increase of weight, and the relation that ought to exist between the diameter of the wheel and the load it has to carry.
26. The various descriptions of Pumps employed for Raising Water or Sewage, and their relative efficiency.
27. The different systems of Lifts in use in Warehouses and Dwellings.
28. The relative Loss of Power due to Friction in various parts of machinery.
29. The 'Output' of Coal in the United Kingdom, as compared

with that of other countries, illustrated by statistics, showing where Coal is produced, where and how it is consumed, and the relative quantities exported.

30. The Appliances and Methods used in different countries for Tunnel-driving, Rock-boring, and Blasting, with details of the cost and of the results attained.
31. The Methods and Machinery employed in sinking and in working deep Coal Mines.
32. Coal Depôts for Ocean Steamers, the various points involved in their management, and the methods of preserving large quantities of coal from deterioration.
33. The Metalliferous or other Mining Districts in different countries, and the mode adopted in working them.
34. The Methods employed in securing the Excavations in mining large and irregular-shaped mineral deposits—for example, the Almaden Mines, the Great Comstock Lode, &c.
35. The Appliances used in different countries for Dressing the Ores of Lead, Copper, Zinc, and Tin, and the Smelting of such Ores, with details of the results and cost by various methods.
36. The Disposal and Utilisation of Slags from various smelting processes.
37. The Management of Underground Waters in mining districts, and the relative economy of distributed or trunk pumping engines, adits, &c., in particular cases.
38. Recent Progress in Telegraphy, with a notice of the theoretical and practical data on which that progress has been based.
39. The application of Electricity to Lighting purposes, contrasted with the best systems of Lighting at present in use.
40. Torpedoes, and their influence on Naval Construction.

---

INSTRUCTIONS FOR PREPARING COMMUNICATIONS.

The Essays should be written in the third person, and be legibly transcribed on foolscap paper, on one side only, leaving a margin on the left side, in order that the sheets may be bound. Every Paper must be prefaced by a concise Abstract.

Illustrations, when necessary, should be drawn on tracing paper, to as small a scale as is consistent with distinctness, and ready to be engraved. When an illustrated communication is accepted for reading, a series of Diagrams will be required sufficiently large and boldly coloured to be clearly visible at a distance of 60 feet. These Diagrams will be returned.

Papers which have been read at the Meetings of other Societies or have been published in any form, cannot be read at a Meeting of the Institution, nor be admitted to competition for the Premiums.

The Communications must be forwarded to the Secretary of the Institution, from whom any further information may be obtained.

CHARLES MANBY, *Honorary Secretary.*
JAMES FORREST, *Secretary.*

THE INSTITUTION OF CIVIL ENGINEERS,
25, *Great George Street, Westminster, London, S.W.*
*October*, 1878.

---

NOTICE.

It has frequently occurred that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would therefore emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions advanced in the Papers or in the consequent Discussions; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry; but that such notice, or award, must not be considered as any expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

---

EXCERPT BYE-LAWS, SECTION XV., CLAUSE 3.

"Every Paper, Map, Plan, Drawing, or Model, presented to the Institution, shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same in any way and at any time they may think proper. But should the Council refuse or delay the publication of such Paper beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing to the Secretary of his intention. Except as hereinbefore provided, no person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution without the previous consent of the Council."

# ORIGINAL COMMUNICATIONS

RECEIVED BETWEEN DECEMBER 1ST, 1877, AND NOVEMBER 30TH, 1878.

AUTHORS.

Airy, W. No. 1,588.—On the Slopes of Cuttings (*post*, p. 241).

Ballard, R. No. 1,565.—Description of an Earth Auger for Pile Foundations. With 9 Photographs and Model.

Bazalgette, E. No. 1,561.—The Victoria, Albert, and Chelsea Embankments of the River Thames (vol. liv., p. 1).

Bell, I. No. 1,564.—La Corbière Lighthouse, Jersey. With 13 Drawings.

„ No. 1,589.—St. Helier's Harbour Works. With 12 Drawings.

Blandy, A. F. No. 1,584.—Dock Gates.

Blood, B. W. No. 1,603.—A Skeleton Pontoon Bridge. With Sketch (vol. liv., p. 249).

Blyth, B. H. No. 1,552.—Description of a Viaduct for Carrying the Caledonian Railway over the River Clyde at Glasgow. With 5 Drawings, 3 Photographs, and 2 Sections of Iron.

Brady, J. No. 1,557.—On the Water Supply of the City of Sandhurst, Victoria, Australia. With 2 Photographs.

Brand, J. No. 1,580.—Results of the Working of Dunbar and Ruston's Steam Navvy (vol. lii., p. 257).

Byrne, H. No. 1,615.—Irrigation in Ceylon.

Clark, D. K. No. 1,585.—On the Strength of Flat Plates and Segmental Ends of Boilers and other Cylinders (vol. liii., p. 170).

Clarke, T. C. No. 1,574.—The Design generally of Iron Bridges of very Large Span for Railway Traffic. With 3 sheets of Drawings and 9 Photographs (vol. liv., p. 179).

Colson, C. No. 1,586.—Portland Cement Concrete in Arches, and Portland Cement Mortar (vol. liv., p. 264).

Douglass, J. N. No. 1,598.—Note on the Eddystone Lighthouse (vol. liii., p. 247).

Flannery, J. F. No. 1,560.—The Construction of Steam Boilers adapted for very High Pressures (vol. liv., p. 123).

Fox, C. D. No. 1,566.—Description of the Excavating Machine or Steam Navvy, with the results of its use on the West Lancashire Railway (vol. lii., p. 250).

AUTHORS.

Gibson, T. No. 1,559.—The Huelva Pier of the Rio Tinto Railway. With Appendix, &c. (vol. liii., p. 130).

Griffith, J. P. No. 1,612.—The Improvement of Dublin Bar by Artificial Scour.

Harrison, C. A.—Results of the working of a Steam Navvy at the West Hartlepool Docks (vol. lii., p. 265).

Hill, J. No. 1609.—Account of two Drainages in Ireland. With 3 Maps.

Holley, A. L. No. 1,568.—Chemical and Physical Analyses of Phosphoric Steel. With 3 Diagrams (vol. liii., p. 221).

Holt, H. P. No. 1,572.—Description of Holt's Telemeter. With 1 Drawing.

„ No. 1,573.—Description of a combined Iron and Timber Roof Construction.

Kilvington, W. No. 1,618.—The Expansion of Steam in Two Cylinders.

Laws, W. G. No. 1,563.—On a Railway Bridge over the River Tyne at Wylam, Northumberland.

Longridge, J. A. No. 1,597.—On the Flow of Water through Level Canals (vol. liii., p. 216).

„ No. 1,601.—Construction of Heavy Ordnance.

Lucas, J. No. 1,614.—The Hydro-geology of the Lower Greensands of Surrey and Hampshire.

Macdougall, A. No. 1,607.—The Degree of Civil Engineer.

Monk, H. L. No. 1,575.—Some of the Apparatus used in India for Sinking Brickwork Cylinders. With 1 Drawing and Models.

Mortimer, J. R. No. 1,554.—The Chalk Water Supply of Yorkshire (*post*, p. 252).

Paterson, M. McC. No. 1,611.—The Testing of Pipes and Pipe Joints in Open Trenches; with a Description of the Ossett Waterworks. With 2 Drawings.

Patterson, R. C. No. 1,619.—On the best Methods of Railway Construction for the Development of New Countries, as illustrated by the Railway Systems of South Australia. With 24 Drawings and Diagrams, and 4 small scale Tracings.

Perram, G. No. 1,610.—Report on the Improvements being carried out on the Irrigation Channels in the Ashtagram Taluk, Mysore District. With 7 Drawings.

Phipson, W. W. No. 1,465.—On the Heating and Ventilating Apparatus of the Glasgow University (*ante*, p. 124).

Pole, W. No. 1,593.—Note on the Ventilation of the Mont Cenis Tunnel (vol. liii., p. 164).

AUTHORS.

Potter, W. F. No. 1,587.—Railway Work in Japan. With 5 Drawings.

Price, J. No. 1,537.—Movable Bridges. With Appendix and 16 Drawings.

Ruston, Proctor, and Co. Remarks on Steam-Excavating Apparatus and its Results in Use (vol. lii., p. 266).

St. George, P. W. No. 1,570.—On Street and Foot-Walk Pavements, Montreal, Canada, from the year 1842 to 1878.

Salmond, T. R. No. 1,553.—The River Lagan and Harbour of Belfast. With 11 Drawings (*ante*, p. 22).

Sandeman, J. W. No. 1,562.—Portland Cement Concrete (vol. liv., p. 251).

Siccama, H. T. H. No. 1,590.—The Delta of the Rhine and the Meuse in the Netherlands. With 15 Drawings.

Stanger, G. H. No. 1,617.—Translation of a Report by the Commissioners of the Peruvian Government, as to the best means of Increasing the Waters of the River Chili.

Stewart, J. No. 1,579.—On the Application of Wire Bond to Circular Structures of Stone, Brick, or Concrete. With 1 Drawing.

Target, J. L. F. No. 1,576.—Experiments on the Heights, &c., of Jets from the Hydrants of the Kingston Waterworks, Jamaica (vol. liv., p. 276).

Thornton, G. No. 1,595.—Description of the Lyttleton Harbour Works, Canterbury, New Zealand. With 3 Drawings.

Unwin, W. C. No. 1,582.—The Centrifugal Pump. With 1 Drawing (vol. liii., p. 249).

Waring, H. R. No. 1,555.—The Drainage, Irrigation, and Cultivation of the Albufera of Alcudia, Majorca; and Application of the Common Reed as a Material for Paper (vol. lii., p. 243).

Williams, J. E. No. 1,577.—Whitehaven Harbour and Dock Works (*ante*, p. 36).

Wilson, G. No. 1,613.—Draining and Improving 1,500,000 Acres of Desert Land (*post*, p. 234).

Wilson, J. M. No. 1,592.—Bridge over the Monongahela River at Port Perry, Pennsylvania Railroad, U.S., for the Pittsburg, Virginia, and Charleston Railway. With 8 Drawings.

## LIST OF DONORS TO THE LIBRARY.

FROM DECEMBER 1, 1877, TO NOVEMBER 30, 1878.

---

A.

Adams, Col. J. W., U.S.A.
Agent-General for New South Wales.
Agent-General for Victoria.
Althans, E.
Anderson, Sir J.
Anderson, W.
Andrew, W. P.
Andrews, E. R.
Ångström, C. A.
Ansted, D. T.
Appleby, C. J.
Armour, J.
Austin, C. E.
Aveling, T.
Ayrton, W. E.

B.

Baccarini, Sr.
Bache, A.
Barlow, P. W.
Barnes, P.
Bartels, H.
Bateman, J. F.
Bauerman, H.
Baumhauer, Dr. E. H. von.
Bazaine, A.
Bazalgette, Sir J. W., C.B.
Beardmore, N. St. B.
Belgrand, E.
Bell, R. B.
Bellingham, W.
Belpaire, T.
Biddell, G. A.
Bigg-Wither, T. P.
Binnie, A. R.
Birch, R. W. P.
Boileau, P.
Bolton, Lieut.-Col. F.
Bonolis, Prof. A.
Bramall, H.
Bramwell, F. J.
Branfill, J.
Brassey, T., M.P.
Briggs, R.
Britten, B.
Brunel, H. M.
Brunon, B.
Bryan, W. B.
Brydges, C. J.
Bull, W. J.
Buren, J. D. van.
Bury, W.

C.

Campurano, Carlos.
Carrick, J.
Carrington, R. C.
Chapman, J. G.
Chesbrough, E. S.
Cialdi, A.
Clark, D. K.
Collins, W. W.
Coode, Sir J.
Cooper, G.
Cotterill, J. H.
Croes, J. J. R.
Croizette-Desnoy M.
Crosby, Lockw & Co.
Crowe, W. M.

D.

Danvers, F. C.
Danvers, J.
Darlow & Co.
Deas, J.
Delesse, M.
De Rance, C. E.
Dickinson, J.
Dixon, J.
Dixon, W.
Donaldson, W.
Duhan, H.
Dunod, M.

E.

Eads, J. B.
Eddy, H. T.
Egleston, Dr. T.
Ellice-Clark, E. B
Evans, W. W.

F.

Field, R.
Flattich, W.
Fleming, S.
Fleming, W.
Fletcher, I.
Fletcher, L. E.
Fliegner, A.
Flowers, C. F.
Forest, E. L. de.
Francis, J. B.
Frost, G. H.

G.

Galton, Capt. D., C.B.
Gamble, J. G.
Gerhardt, C.
Gilbert, Dr.
Gordon, J.
Goslin, S. B.
Gottschalk, A.
Gower, F. B.
Greaves, C.
Griffiths, J. A.
Grover, J. W.
Grüner, L.
Gulland, J. K.

H.

Haddan, J. L.
Harlacher, A. R.
Haughton, B.
Hawkins, C. E.
Hayden, F. V.
Hayter, H.
Haywood, W.
Hickson, R.
Higgin, G.
Hille, F.
Holley, A. L.
Holt, A.
Howell, Capt. C. W., U.S.A.
Huet, A.

I.

Inch, B. H.
Inglis, J. C.
Institution of Mechanical Engineers, The.

J.

Jacob, Maj.-Gen. Sir G. Legrand.
Jones, H.
Jones, Lieut.-Col. A. S., V.C.
Johnston, T. M. Hardy.

K.

Keller, K.
Kennedy, J.
Kimber, J.
King, J. W.
Kingsford, W.
Knapp, C.
Knapp, H. F.
Kirkman, M. M.
Kreuter, F.

L.

Latham, B.
Lauber, E.
Laur, F.
Leach, S. W.
Lean, Miss.
Ledebur, Prof. A.
Ledoux, M.
Lesage, L.
Light, A. L.
Lindley, W. H.
Lindsay, Lord.
Longridge, R. B.
Lovegrove, J.
Lovett, T. D.
Lyman, B. S.

M.

Macassey, L. L.
Maganzini, I.
Mallet, L.
Manby, C.
Mansergh, J.
Marsden, H. R.
Marsh, L.
Matheson, E.
Matheson, H. M.
McBean, S.
Meldrum, C.
Melisurgo, G.
Messent, P. J.
Meunier-Dollfus, C.
Millar, W. J.
Mitchell, J.
Molesworth, G. L.
Morant, A. W.
Morris, T.
Mott, H. A.
Müller, Dr. F. C. G.
Munroe, H. S.

N.

Newbigging, T.
Nicolls, W. J.
North, E. P.
Nourse, Prof.

O.

Oldham, J.
Oldham, R. A.

P.

Paris, Admiral, E.
Parry, J.
Parsons, Hon. R. C.
Pascal, M.
Passos, Dr. F. P.
Paul, Dr. B. H.
Pendred, V.
Périssé, S.
Perry, J.
Phillips, D.
Phillips, J. A.
Podhagsky, J. von.
Pole, Dr.
Ponsonby & Murphy, Messrs.

Q.

Quinette de Rochemont, Baron.

R.

Rapier, R. C.
Ravenhill, J. R.
Reade, T. M.
Rechberg, Dr. von S.
Rees, J. C.
Reeves, F. W.
Reid, H.
Rinecker, F.
Ritter, A.
Robinson, H.
Rowan, F. J.
Rumball, A.
Roulz - Montchal, Count Henri de.
Russel, J. B.
Rzĭha, R.

S.

Sabine, R.
Sandberg, C. P.
Schram, R.
Schwebélé, C.
Schwedler, J. W.
Schwendler, L.
Selwyn, Admiral, J. H.
Sherwood, Grubbe, & Co., Messrs.
Shoolbred, J. N.
Siemens, C. W.
Silver, S. W.
Simms, Dr. F.
Sims, R. P.
Smyth, P.
Stáně, A.
Stanley, W. F.
Stayton, G. H.
Stévart, A.
Stevenson, D.
Stoecklin, —.
Stoney, B. B.
Street, W. C.
Streeter, E. W.
Symons, C. J.

T.

Tarbotton, M. O.
Thurston, R. H.
Towle, H. E.
Tucker, J. S.
Tuson, J. F.
Twining, T.

U.

Unwin, W. C.
Urquhart, J.

V.

Van Nostrand, D.
Vauthier, L. L.
Vyse, G. W.

W.

Walch, G. T.
Watson, Dr. W.
Whipple, G. M.
White, W. H.
Williams, J. E.
Wilson, R.
Winkler, Dr. E.
Wittmann, Dr. W.
Woods, E. H.

The Subscriptions to the Library Fund were as follows:—

| | £ | s. | d. |
|---|---|---|---|
| Blackbourn, Henry | 1 | 1 | 0 |
| Bray, William Bayley | 5 | 5 | 0 |
| Brodie, William Patrick | 3 | 5 | 11 |
| Burnett, Robert Reginald | 1 | 1 | 0 |
| Clough, Charles Frederic | 1 | 10 | 0 |
| Gooch, Henry | 1 | 1 | 0 |
| Groves, Leonard | 1 | 1 | 0 |
| Hart, James | 1 | 11 | 6 |
| Hepworth, Joseph | 2 | 2 | 0 |
| Jones, Edward John | 2 | 2 | 0 |
| Kilvington, William | 5 | 0 | 0 |
| Mackintosh, Peter Arthur | 1 | 1 | 0 |
| MacGeorge, G. W. | 2 | 2 | 0 |
| Ogilvie, Charles Edward Walker | 10 | 10 | 0 |
| Slade, Frederick | 1 | 1 | 0 |
| Stevens, Warwick | 3 | 3 | 0 |
| Tate, John | 1 | 1 | 0 |
| Venables, William Henry | 1 | 1 | 0 |
| Ward, Henry Thomas Simpson | 5 | 0 | 0 |
| | 49 | 19 | 5 |

# OFFICERS.—1878-79.

## Council:

**PRESIDENT.**

JOHN FREDERIC BATEMAN, F.R.SS. L. & E.

**VICE-PRESIDENTS.**

| | |
|---|---|
| JAMES ABERNETHY, | WILLIAM HENRY BARLOW, F. |
| *Sir* WM. G. ARMSTRONG, C.B., F.R.S., | JAMES BRUNLEES, F.R.S.E. |

**MEMBERS.**

| | |
|---|---|
| WILLIAM BAKER (since deceased), | ALFRED GILES, M.P., |
| *Sir* JOSEPH WM. BAZALGETTE, C.B., | HARRISON HAYTER, |
| GEORGE BERKLEY, | WILLIAM POLE, F.R.SS. L. & |
| FREDERICK JOS. BRAMWELL, F.R.S., | ROBERT RAWLINSON, C.B., |
| GEORGE BARCLAY BRUCE, | C. WILLIAM SIEMENS, F.R.S., |
| *Sir* JOHN COODE, | DAVID STEVENSON, F.R.S.E., |
| WILLIAM FROUDE, M.A., F.R.S., | *Sir* JOS. WHITWORTH, BT., F. |

EDWARD WOODS.

## Honorary Councillors:

**PAST PRESIDENTS.**

| | |
|---|---|
| *Sir* JOHN HAWKSHAW, F.R.S., | THOMAS HAWKSLEY, F.R.S., |
| JOHN FOWLER, | THOMAS ELLIOT HARRISON, |
| CHARLES HUTTON GREGORY, C.M.G., | GEORGE ROBERT STEPHENSON. |

## Officers:

**AUDITORS.**

| | |
|---|---|
| ALFRED RUMBALL, | WILLIAM BOURNE LEWIS. |

**TREASURER.**

HUGH LINDSAY ANTROBUS.

**HONORARY ARCHITECT.**

THOMAS HENRY WYATT, F.R.I.B.

**HONORARY SECRETARY.**

CHARLES MANBY, F.R.S.

**SECRETARY.**

JAMES FORREST.

*** *This Council will continue till December* 1879.

## SECT. II.—OTHER SELECTED PAPERS.

No. 92.—"The Eastern Canal of France; for establishing a line of Water-Communication from the Saône to the Meuse."[1] By WILLIAM BELL DAWSON, B.A., B.A.Sc., Stud. Inst. C.E., Past Pupil of the École des Ponts et Chaussées, Paris.

BEFORE the war of 1870, two important lines of water-communication united with each other at Strassburg; one, passing between the Vosges and the Jura, connected the northern tributaries of the Rhone with the Rhine; the other, leaving the Seine at Paris, took a direction almost due east, and met the Rhine at the same town. The loss of Alsace and Lorraine rendered it necessary to unite these two lines by a new canal, running north and south on the west side of the Vosges, in order to preserve their connection upon French territory. It was also decided that this new line should be prolonged to the coal-fields of Belgium. A navigable route in this direction had long been asked for by the Eastern Departments, and a scheme for its execution had been drawn up before the war, which had to be abandoned on account of the new position of the German frontier. The request itself became more urgent, as many of the large manufacturers of Mulhausen and elsewhere, who had re-established themselves upon French soil, were in great need of the cheap mode of conveyance which water-communication alone can afford, both for the fuel they required, and for the heavy articles of their manufacture. The valley of the Meuse forms a natural channel, lying precisely in the direction wished for; so that the improvement of its navigation, from the point at which the canal from Paris to Strassburg crosses it, furnishes an obvious solution to this part of the question. As several towns of importance are situated upon that river, their interests would also be met by its improvement.

The navigation of the Rhone is prolonged to the north along the Saône, which has been canalized to within a short distance of its source, and forms, therefore, the nearest and most accessible of the

[1] This communication was read and discussed at a meeting of the Students on the 29th of March, 1878, and was awarded the Miller Scholarship in the Session 1877–78.—SEC. INST. C.E.

tributaries of the Rhone to the canal from Paris to Strassburg. To reach it from the canal, either the Meuse or the Moselle might be chosen, as both these rivers are crossed by the canal. The Meuse, however, soon diminishes to a small stream above this point; and the tributaries of the Saône nearest to its source are but rapid brooks for a considerable distance, while the water-shed separating them is formed of hills difficult to cross. The Moselle is much larger, and, after some distance, runs parallel to the water-shed separating it from the basin of the Saône a short way from its left bank. A choice is thus afforded, as the Moselle is still a large stream, and the tributaries of the Saône are numerous. The one selected was a small stream called the Coney, whose source is within 5 miles of the important town of Épinal, on the Moselle. The connection of the two rivers can be effected without tunnelling —which is certainly remarkable, considering that they are separated by one of the primary water-sheds of Europe; and it shows the natural advantages of the point chosen.

The scheme under consideration consists, then, in the construction of a line of water-communication upwards of 280 miles in length, having a general north and south direction, and running through the five Departments of the Haute Saône, Vosges, Meurthe-et-Moselle, Meuse, and Ardennes. It is comprised under the name of the Eastern Canal (*Canal de l'Est*) (Plate 7), and it affords a navigable route to Belgium and the North Sea on the one hand, and to the Rhone and the Mediterranean on the other.

The depth of water in the Marne-Rhine Canal, as the canal from Paris to Strassburg is called, is 5 feet 3 inches. The locks are 17 feet wide, and 125 feet long. The Saône is already canalized as far as Port-sur-Saône, up to which the draught of water and width of the locks is the same as in the Marne-Rhine Canal. Their length, however, is only 114 feet.

On the Eastern Canal also the locks are to be 17 feet wide, but the depth of water will be 6 feet 6 inches. Their length is 131 feet 3 inches between the mitre-sills (Plate 8, Figs. 1 and 2). The lift-wall is double, the floor of the head-bay being at a level intermediate between the bottom of the reach above and the floor of the lock. The object of this arrangement is that the sluices in the head-gates may always be under water, even when the tail-gates are open, so that the boats may not be inconvenienced by the water pouring down upon their decks while the lock is being filled. This increases somewhat the amount of ashlar masonry, as well as the height of the head-gates (Plate 8, Figs. 4, 5, and 6); but there is economy on the whole, as ordinary gates with sluices

are thus given all the advantage, without the expense, of side culverts.

In accordance with Acts passed on the 15th of April and the 7th of August, 1871, the Minister of Public Works directed the engineers in his department to commence preliminary surveys, and to draw up reports upon the proposed scheme. The estimated cost of the works was £2,600,000; and as the Government was unable, so soon after the war, to furnish this sum, it was arranged that the amount should be made up by the five Departments interested, and that they should be repaid in annual instalments. The whole work of surveying, location, and construction was undertaken by the Government, and the canal is eventually to become Government property. The date fixed for the completion of the work is May 1882.

The scheme consists naturally of two parts; the first to be considered is the plan for connecting the Marne-Rhine Canal with the Saône, as it has been proposed and partly carried out.

### The Canal from the Moselle to the Saône.

The Marne-Rhine Canal is already connected with the Moselle near Toul by a short branch, which serves at the same time to supply the canal with water. This forms a starting-point for the new canal, which then ascends the Moselle as far as Épinal. The Moselle here flows in a narrow valley, varying in general from a ¼ to ½ mile in width, and enclosed between hills from 200 feet to 300 feet in height. The current is rapid, as the fall averages 6 feet in the mile, and the volume of water passing Toul is 118,000 gallons a minute. Several mill-dams and weirs, built partly across the river, occur in this part of its course, although the greater portion of the water-power derived from the river is in the vicinity of Épinal, and above that town. Nothing had previously been done to render the river navigable, and in the Government reports it is merely classed as *flottable*, *i.e.* suitable for the conveyance of firewood in logs. It was found advisable to abandon the channel in many places; and the plans, as finally approved, show by much the greater part of the work constructed as a lateral canal.

On reaching Messein, a branch crosses to the valley of the Meurthe, and unites with the Marne-Rhine Canal a little above Nancy. This is called the Nancy branch, and is of great importance to that town, as it makes the communication with the upper part of the Moselle much more direct. Its length is 7¼ miles. The summit reach on this branch is 144 feet above the level of the

Meurthe at Nancy, while it is only 69 feet above the Moselle at Messein. This latter river is, therefore, more suitable as a source of supply, and was resorted to, as there are no lakes or streams of importance in the neighbourhood of the summit. The water is derived from the Moselle, a short distance above Flavigny, where a mill-dam raises the level of the water in the river; a new dam will be constructed to increase the height of the water. From here to Messein an aqueduct, consisting of an open trench 16 feet 5 inches wide at the bottom, and with slopes at 1½ to 1, is being excavated; it follows the right bank of the Moselle, and passes under the first arch of the bridge on which the canal crosses the river at Flavigny, below which there is a branch leading to the factory supplied by the former mill-dam; it then runs between the canal and the river, and enters one of the reaches, which is brought purposely to the same level. This part of the aqueduct is navigable for small boats, and serves to join the canal with the Moselle, thus enabling wood cut along the banks to be brought into the canal. A guard-lock on the aqueduct near the point where it meets the canal, with a pair of gates opening in each direction, severs the connection with the river when the canal is emptied for repairs. From the lower end of this reach, the aqueduct is continued along the side of the hill above the canal; crossing the Nancy branch on the level, above the first lock, it arrives at Messein, where a portion of the outfall is used to work hydraulic engines, which raise the remainder of the water to the summit reach.

The bridge at Flavigny, for carrying the canal across the Moselle is of masonry. The level of the canal is kept as low as possible to avoid heavy embankment, as far as the bridge, where it ascends 16½ feet by means of a lock, continuous with the masonry of the bridge. The hills on the other bank are close to the river, so that the reach, of which the bridge forms part, can be extended along them in cutting without difficulty. The foundations of the bridge are rather peculiar. The danger of scour was considered so great, on account of the rapidity of the current in time of flood and the gravelly nature of the bottom, that a flooring of concrete, level with the bottom, was laid completely across the river. Its width is about 25 feet greater than the length of the piers, and the concrete flooring is so placed as to extend 15 feet beyond them down stream, and 10 feet on the up-stream side. It was built in two parts, in coffer-dams extending from the banks. The depth of the excavation was 10 feet below the summer level of the water. The piers, 6½ feet thick, stand upon this slab

concrete. The rise of the arches is one-tenth of the span. When they are completed and the centres struck, the extrados will be coated with a layer of cement to prevent leakage, before the channel of the canal is commenced, and it also will be lined with cement. This mode of foundation has already been successfully employed several times in France. As far back as 1750, M. de Régemortes built a bridge in this way across the Allier, whose rapid current and sandy bed had previously caused the destruction of several bridges. The edges of the concrete were protected above and below by several lines of heavy sheet-piling. The same method was again adopted in the construction of a bridge carrying a canal across the same river; and also for a railway-bridge crossing a little higher up. The thickness of the concrete in these cases varies from 5 to 6 feet.[1]

Above Flavigny the canal follows the left bank of the Moselle till it arrives at a point 2 miles below Épinal. Very little has yet been done on this part of the line, and no works occur of special interest. At this point the main line of the canal turns abruptly from the river, its direction being prolonged as far as Épinal by a short branch, which connects this town with the canal, and derives a supply of water from the river.

A portion of the canal now follows, in which the question of the supply of water and of economy in its use becomes of primary importance. The hills lying between the Moselle and the sources of the Coney form a spur of the Vosges, and consist for the most part of soft red sandstones, known as the variegated sandstone (*Grès bigarré*), on account of their streaked and spotted appearance. These form the lower member of the Trias. On the slopes towards Épinal, beds of a considerably harder grey sandstone occur. This is the Vosgian sandstone (*Grès des Vosges*) of the upper Permian. They are together a conformable series, dipping at a low angle toward the north.

The summit reach is 1,182½ feet above sea-level,[2] and is a little over 7 miles in length. There is a considerable amount of rock cutting upon it, and at the end farthest from the Moselle, where the water-shed is actually crossed, the depth of cutting is 48 feet measured to the water-level of the canal. The level of the water in the reach common to the Épinal branch and to the main line of the canal is 1,036½ feet above sea-level, leaving a height

[1] For drawings of these bridges see 'Morandière, Traité de la Construction des Ponts et Viaducs,' Plate 11.

[2] The level of the Mediterranean is taken as datum.

of 146 feet to be ascended in a distance of less than 2 miles. To reduce as far as possible the amount of water required to take a boat up this ascent, it was decided to make the locks separate and not in a flight; and further, that they should all be of equal lift, and that the lift should not be great. The lift chosen was 9 feet 10 inches, which gives fifteen as the required number of locks. Less water would be consumed if the amount of lift were lessened, but this would be difficult to effect, as it would necessitate an increase in the number of the locks. Most of the reaches are short, and it was considered essential that the locks should be situated upon tangents at least 160 yards in length, so that boats might not be inconvenienced by coming upon the commencement of a curve before they were completely out of the lock. The curves are rather sharp as it is, and any further increase in the number of the locks would render it difficult for the boats to pass them, as the valley by which the ascent is made is a narrow one. The reaches between the locks are so short, and their surfaces, if the usual width of 52½ feet at water-level were given to them, would be so small, that when the quantity of water necessary to fill a lock was drawn from them they would be no longer navigable. To obviate the difficulty no bank was constructed on the side opposite the tow-path, but the water of the canal was allowed to extend across the valley, till it met the sloping ground forming its opposite bank. This part of the canal consists, therefore, of a series of ponds, one above the other, occupying the bottom of the valley. They are separated from each other by dams of earth across the valley, terminating at one end against the outer side of the lock walls, and extending to the slope on the right side of the valley. They are placed at the lower end of the lock, in order that the area of the ponds may be as great as possible. This plan, for which the natural shape of the valley was particularly well adapted, gave to the reaches surfaces which vary from 9,500 square yards to 24,000 square yards. The smallest of the ponds has, therefore, an area equal to a length of nearly 550 yards of canal of the usual width; and when water is drawn off on a boat passing through the lock below, its level will be lowered only 3 inches. The draught of water in the channel adjoining the tow-path is here increased from 6 feet 6 inches to 7 feet 4 inches, so that the water may be allowed to fall 10 inches without interrupting the circulation. This corresponds, in the smallest pond, to the quantity of water necessary to fill a lock three times. The level of the water can also be raised 12 inches, if water be required for the supply of the pond below. Several of the locks have been placed in the position

they occupy in order that the dam extending from them might serve to re-establish the communication along roads crossing the valley. The position of the remaining locks has been determined by the slope of the ground, combined with the condition of their being on a tangent of given length, as already mentioned. The dams retaining the water in the ponds are 9 feet 10 inches wide on the top, and extend 3 feet 3 inches above the level of the water, a height which allows for the level being raised occasionally, and for the action of waves, as sudden gusts of wind are frequent in this hilly region. The thickness increases to 21 feet 7 inches at the level of the water, and the slopes continue below this level at $1\frac{1}{2}$ to 1. A small waste-weir in each dam, at the end farthest from the lock, allows any surplus water to pass into the pond below. The work on this part of the canal is now actively in progress, and great care is being taken to render the dams water-tight. Much of the earth used in their construction is brought from the cuttings on the summit reach. It is conveyed in wagons running upon rails, and when tipped, is spread with shovels in thin layers and well rammed, as required by the specification in all such cases. The embankments which form the sides of the canal towards the lower ends of the reaches are treated in the same way.

In calculating the amount of water required for the summit reach, the annual tonnage passing through the canal is taken at 1,000,000 tons, of which one-half is assumed to be local traffic for the conveyance of stone and fire-wood from the summit to the navigable rivers on the one side or the other, and the rest through traffic. This tonnage is nearly twice the present annual amount on the Marne-Rhine Canal, and must be considered as allowing an ample margin for the future development of commerce. The number of days in the year suitable for navigation is estimated at three hundred, as there is always a considerable period towards the spring when floods render the rivers impassable, and in summer their level may be too low. This gives 1,700 tons a day for each kind of traffic. With boats carrying 100 tons, there would therefore be $34 + 17 = 51$ lockfuls of water drawn off each day from the summit reach. The loss by percolation and evaporation is estimated at 100 gallons a day per lineal yard. On multiplying this by the length of the canal on the two slopes, and adding the amount of water required for lockage, the total daily consumption is found to be 9,418,000 gallons—equivalent to 6,600 gallons per minute (half a cubic mètre per second).

The original plan, suggested in 1872, for obtaining the necessary amount of water was to construct an aqueduct which would derive

its supply from the upper waters of the Moselle and from its tributary the Vologne, and following the hillside forming the left bank of the Moselle would fall into the summit reach at the end nearest Épinal. The level of these rivers where the supply would be obtained is such as to afford a sufficient fall for the aqueduct, and a volume of water double that required could be taken from them during six months of the year without infringing upon the rights of the mill-owners in the valley. For the remaining six months an additional supply could be obtained from the lakes of Gérardmer and Longemer near the sources of the Vologne, by storing up the winter rainfall for use in summer. Water would be let out during the dry season, and, finding its way down the natural channel of the Vologne, would be conveyed by the aqueduct to the canal. Much of the water in passing down the Vologne would be drawn off for the irrigation of meadows, and in this way considerable loss might be expected to occur. The essential defect of the project, however, is found in the circumstance that the supply of water is stored at so great a distance from the canal. The summit reach contains 132,000,000 gallons, and if emptied for repairs it would take eight or ten days to refill it; whereas on the Marne-Rhine Canal only three days are needed for re-establishing the navigation. There is always a delay in the arrival of the supply, which, in the case of a press of traffic or of any accident, might prove to be a serious inconvenience. To meet the difficulty it was determined to construct in addition a reservoir near the summit reach. A suitable position was found in the upper part of the valley of the Avière, a small stream tributary to the Moselle. It was called the Bouzey reservoir, from a little village in the neighbourhood, and derives its supply from the basin, 4,000 acres in extent, in which it was situated. The annual rainfall is 9·8 inches, and the reservoir was accordingly calculated to hold 907,000,000 gallons. This capacity could easily be given to it by the construction of a retaining wall across the valley; but as there are important starch works in the lower part of the valley, their claims to remuneration for being thus deprived of a large part of the water upon which they depended would have to be satisfied.

Soon after the necessity for the construction of the Bouzey reservoir was admitted, it became apparent that it might be extended so as to serve for the storage of all the water required during the dry season. The supply would thus be kept in the immediate neighbourhood of the canal, which would be an immense advantage, and do away with the necessity of having recourse to the far-distant lakes at the sources of the Vologne. It was found that the

capacity of the reservoir could be nearly doubled, while the expense of doing so merely increased in the ratio of the volumes of water impounded. The raising of the water-level in the reservoir made it necessary for the beginning of the aqueduct to be placed further up the Moselle. The supply is therefore derived from the mill-dam of the factories of St. Etienne, near Riremont, about 8 miles above the point at which it was originally proposed to draw off the water for the canal. The aqueduct commencing here follows the left bank of the Moselle, parallel to the direction marked out for the former one, but at a higher level, till it falls into the Bouzey reservoir.

The quantity of water for the supply of the canal being 9,418,000 gallons a day, the amount required annually is 9,418,000 × 300 = 2,825,000,000 gallons. Adding the quantity necessary to fill the summit reach after the annual interruption in the navigation, the total annual amount reaches 2,957,000,000 gallons. It remains, then, to be ascertained whether this amount can be taken from the Moselle at Riremont without injury to existing rights. In summer the St. Etienne factories use the whole volume of water which the Moselle furnishes to their mill-pond; but when the water overflows the dam, all rights are satisfied, and the surplus is not used. For the supply of the canal one half of the surplus is counted upon and appropriated. From careful observations, it was found that the number of days in the year during which the overflow of the dam would exceed 52,000 gallons per minute could safely be assumed to be one hundred and sixty. Taking half the amount, the quantity of water which could be conveniently drawn from the river is 5,790,000,000 gallons per annum. The length of the aqueduct is very nearly 27 miles, and the loss from leakage is assumed to be 50 gallons a day per lineal yard, which is half that of the canal, and must be considered an ample allowance. The annual loss from this cause is therefore 380,000,000 gallons, so that 5,410,000,000 gallons reach the Bouzey reservoir. It will be observed that this quantity is nearly double the amount calculated to be sufficient for the canal. An ample supply of water can therefore be derived from the Moselle without interfering with the rights of the mill-owners, and can be stored in the immediate neighbourhood of the summit reach. An aqueduct giving an outfall of 26,400 gallons per minute is found to be sufficient for its conveyance; and although this aqueduct carries double the amount of water and is one-third longer than the one originally projected, and falls into a reservoir of nearly twice the capacity of that first proposed, the cost of carrying out the scheme

is within 3 per cent. of the former estimate. The longest continuous interruption to the supply, as shown by the observations, was in 1868, when it amounted to a period of one hundred and thirty-six days. Taking one hundred and forty days as a maximum, and allowing 0·3 inch per diem as the rate of evaporation, the capacity of the Bouzey reservoir is 1,470,000,000 gallons.

The crest of the St. Etienne mill-dam is 1,261 feet above sea-level, and the total fall available for the aqueduct is therefore 43 feet. The whole fall is not utilised; but the higher level of the aqueduct thus secured facilitates the passing of the villages on the banks of the Moselle. The aqueduct is mostly an open trench cut in side-long ground, and having a longitudinal inclination of 1 in 10,000. Its dimensions are:

| | |
|---|---|
| Width at the bottom | 5 feet 7 inches. |
| Slope of the sides | 1½ to 1. |
| Depth | 6 feet 7 inches. |
| Width at the top | 25 feet 3 inches. |
| Depth of water | 4 feet 11 inches. |
| Sectional area of water | 63¾ square feet. |
| Velocity of current[1] | 1·131 foot per second. |
| Outfall | 26,985 gallons per minute. |

At one point, where the hillside forming the left bank of the Moselle stands at a slope of from 30° to 40°, and consists of sand and gravel, a cylindrical brick conduit is laid at the same inclination as the rest of the aqueduct, so that the water occupies only part of its section. It was constructed in a shored trench, which was afterwards filled, so as to leave the natural slope of the ground unbroken. Where secondary valleys are met with, they are crossed either by making a detour or by an inverted siphon. The siphons consist of two cast-iron pipes, laid side by side, having an internal diameter of 3 feet 9 inches. The difference of level between their upper and lower ends is reckoned at the rate of 1 foot for every 500 feet of their length, measured along the pipes.

At the end near Épinal, two tunnels are being constructed for the conveyance of the aqueduct in order to avoid long detours, which, in addition, would pass close to the town, where the price of land is high. They are nearly of equal length, and traverse for the most part the Grès des Vosges. In the estimate it is assumed that they will require a masonry lining throughout their entire length; but, except at the extremities, this will scarcely be neces-

[1] Calculated from the tables of Bazin given in 'Recherches expérimentales sur l'écoulement de l'eau dans les canaux découvertes.'

sary. In section the lining is egg-shaped. It is semi-circular below, with a diameter of 4 feet 3 inches, and pointed above, the whole height being 6 feet, with a thickness of 14 inches. The longitudinal inclination to ensure the necessary outfall is 6 in 10,000.[1] Where the masonry is not built, it is expected that the increase in the sectional area will more than compensate for the irregularity of the walls, so far as the flow of water is concerned. The tunnels have been commenced from both ends, and as the longer of the two is only 1,563 yards in length, it is not intended to sink intermediate shafts. The drifts are similar to those excavated in the hills of the neighbouring Departments in mining for iron ore. They are timbered as far as the work has yet extended, as the rock for some distance from the surface is softened by atmospheric action; and as it is much fissured and jointed, timbering may be required throughout. The rock is blasted with powder, and its consistency is such that the explosion disintegrates it into sand. A small rotating fan, worked by hand, is placed near the entrance to the tunnel, and forces air through a light sheet-iron pipe, about 1 foot in diameter, to the head of the work. By giving this a few turns after each blast the men can return at once to their work. A tramway serves for the conveyance of the excavated material. The quantity of water met with is considerable, but it is easily disposed of; as even at the upper end, where the inclination of the tunnel is in the direction of the work, side ditches can be cut with a counter-gradient sufficient to carry the water back to the entrance. The rate of advance, based upon measurements made in the mining districts, is taken to be 16 yards per month at each heading.

The Bouzey reservoir, into which the aqueduct discharges, is in the valley of the Avière. It is no longer necessary to prevent the water flowing in this stream from leaving the reservoir, as was intended in the original scheme, for the supply is now independent of the rainfall in its basin. It was desirable to place the retaining dam as near as possible to the canal, in order to increase its area; but as an old quarry exists near the canal, it was thought prudent to put the dam at least 50 yards above it. The valley in question is formed of a streaked reddish sandstone (*Grès bigarré*), much jointed; but as ponds were found in the valley, it was inferred that the leakage would not be so great as to make the establishment of a reservoir impossible. It

[1] The gradient of 6 in 10,000 amounts to a fall of less than 17 inches on half the length of the tunnel.

was ascertained by borings that the sandstone maintains its fissu and jointed character for a considerable depth, below which the l become solid and continuous. The height of the dam require 58 feet at the centre of the valley. As it would be difficult to c struct a substantial earth dam of such dimensions, and little ea was to be had in the vicinity, it has been decided to build i masonry. The wall will not be completed to its full heigh first, as the capacity of the reservoir is sufficient for the prob traffic of the canal for some years to come; but the dimens will enable it to be raised to its final height by simply adc the part left unbuilt. According to the designs prepared for retaining wall, the width of the top is 13 feet. This wi though less than usual, is considered sufficient to resist action of any waves likely to arise on a surface which has only extent of 247 acres. Its height above the level of the wate nearly 2 feet, and there is in addition a parapet 3 feet 3 inc high on the side next the water. The inner face is vertical. curve of the outer face is so calculated that the pressure n nowhere exceed 156 lbs. on the square inch. The sandstone used the masonry has a specific gravity of from 2·0 to 2·2. Wl soaked with water, this is increased to from 6 to 8 per cent., a by taking these higher values of the specific gravity, the maxim pressure is found to be less, as the curve of pressure approac the vertical. The stone crushes under a pressure varying fr 2 to 4 tons per square inch, and will be built with hydraulic li from Theil.

The foundation of the wall presents much difficulty. On right side of the valley the ground is the more favourable, as th the rock is solid and impermeable at a depth of from 10 to 20 feet below the surface. At the centre of the valley ther a bed of peat 28 feet thick, but below it the rock seems very c pact. On the left side of the valley the upper beds are comple broken up into loose blocks, separated by wide cracks, and foundations will there have to be taken down to a consider depth. It is not necessary, however, that the whole thickne the wall should rest upon the impermeable beds, as the main b of the masonry can have as a foundation any of the beds ab whether they be fissured or not. A guard wall, 6½ feet thick, be carried down vertically below the inner face of the wall ti reaches the impermeable beds. At the right side of the valley masonry will end abruptly against the rock, which is here highly clined, and there will be no difficulty in making the connection; on the other side it will be necessary to prolong the wall by tun

ling into the hillside to a distance of 180 feet, in order to prevent the water from passing round its end. At this point the surface of the impermeable beds is only 6 feet below the level of the water in the reservoir, and as the rock is covered with a thick layer of compact soil, it is not thought likely that there will be any leakage worth considering. The reservoir is to be provided with a waste-weir, and the usual tower containing the outlet and emptying valves.

The canal, on leaving the summit reach, descends the valley of the Coney, Plate 7, till it reaches Port-sur-Saône. The distance is nearly 56 miles, and the locks have the same fall (9 feet 10 inches) as on the other side of the summit.

## The Canalization of the Meuse.

The second part of the scheme under consideration consists in the canalization of the Meuse, from the point at which the Marne-Rhine Canal crosses it to the Belgian frontier, a distance of 172 miles.

The Meuse in this part of its course flows through two regions of very dissimilar character. As far as Charleville the valley for about 1 mile in width is occupied by meadows whose surface is nearly level. Beyond these on each side the ground rises rather abruptly to a height of 200 feet or 300 feet. The channel of the Meuse winds through these meadows, and its summer level is only about 3 feet below their surface. The volume of water is not very variable, and yet the least flood inundates the whole valley from side to side. Below Charleville the river enters a mountainous region, and the valley becomes narrow and circuitous. The slope throughout is uniform, varying from 2½ to 3½ feet per mile, while above Charleville the winding of the river reduces the fall to an average of 1 foot in the mile.

The Meuse above Verdun is still in a natural condition. No project for improving it was ever drawn up until it was decided that the Eastern Canal should follow its valley. Here the nature of the valley makes the system of weirs and ponds, so much employed in France, inapplicable. The construction of a lateral canal has been preferred, as there is every facility for it in so wide a valley. The improvement of the channel of the river would be more expensive, and it has therefore been avoided, except in passing through the towns of St. Mihiel and Verdun.

Below Verdun the width of the valley is not quite so uniform. In several places an appreciable slope commences immediately upon each side of the river, and the hills bounding the valley

approach each other. It is at these narrow points that the principal towns along the river are situated. An additional difficulty is thus presented to its canalization, as the channel of the river has to be followed in passing through them. The rebuilding of bridges, and the construction of retaining-walls, is thus often rendered necessary; while there is little space for the tow-path along the bank. These remarks apply to St. Mihiel and to Verdun as well as to the towns below. In almost every instance mill-dams, some of which are very ancient, exist at these towns. This circumstance suggests the probable reason for their having grown up on the sites which they now occupy, as the intervening parts of the river are extremely unfavourable to the construction of dams, thus preventing the establishment of mills and manufactories.

The mountainous region of the Ardennes, which the Meuse enters at Charleville, continues to the frontier and extends into Belgium. It is supposed to be of Silurian age, and consists of highly-inclined schists and slates, which are extensively quarried. This part of the river, although circuitous, has always been navigable; and at certain seasons large boats can ascend it, while in summer the shoals reduce the depth in some places to 18 inches. Mill-dams no longer occur, as the river is rather large to utilise in this way. The country is thinly peopled, there being no villages except in the valley of the river; little can be done in the way of farming in the country around. The hills do not produce much timber, as the trees are usually cut for poles, and these and tan-bark are the principal vegetable productions. There are important industries, however; and in addition to the slate quarries, and limestone quarries in the vicinity of Givet, the manufacture of iron is carried on, for which Belgian coal is used.

Although the canalization of the Meuse has been discussed since the beginning of the century, it was not until 1861 that a project was authorised for the construction between Verdun and Sedan of side-cuts and locks, by which the mill-dams could be passed, and the mill-ponds, which are 6 feet to 10 feet deep, could be utilised for navigation. The draught of water was to be 3 feet 11 inches. It was intended at the same time to construct a canal to connect the Meuse and the Moselle by the valley of the Orne, a small tributary of the latter river, a little below Metz. When the war of 1870 broke out, the side-cuts and locks along the Meuse had been completed, but the intervening portions of the channel of the river had not been deepened. In 1871 when the prosecution of the works again came under notice, it was found that the latter part of the project would have to be abandoned, as a portion of

the country which the canal would pass through was lost to France. The new position of the German frontier, together with other changes brought about by the war, led to the scheme of the Eastern Canal, as has already been explained, and of this project the canalization of the Meuse formed a part.

The Marne-Rhine Canal crosses the watershed between the Marne and the Meuse, near the village of Mauvages, after which the summit reach is named. The slope thence is all in the same direction as far as Toul, as the canal is carried across the valley of the Meuse by a reach 11½ miles in length, on which there is a masonry bridge over the Meuse. This is called the Pagny reach from a small village in the vicinity. By this arrangement a summit is avoided between the Meuse and the Moselle; and the question of water-supply is much simplified, as a group of springs found upon the west bank of the Meuse near the village of Vacon became available for the supply of the Pagny reach, and the surplus was led by it to the series of locks descending towards Toul. The most convenient point at which the Eastern Canal can leave the existing one is on this long reach, where, after following the right bank, it turns abruptly to cross the valley of the Meuse. Thence it descends by a rapid succession of locks to the river, about 4 miles off. As the section of the Eastern Canal which connects the Marne-Rhine Canal with the Saône commences at Toul, a portion of the existing canal is common to both, and the Pagny reach becomes a summit reach on the new line of canal. From it is drawn off the water required for the Eastern Canal as far as the Meuse. It has been found necessary to increase the depth of water from 5 feet 3 inches to 6 feet 7 inches on this reach and along the canal as far as Toul, which not only makes the leakage of the canal greater, by augmenting the pressure upon its sides, but also increases the volume of water necessary to fill the locks; and as the traffic of both canals will pass along this portion, the demand made upon the Pagny reach becomes very great. The supply of water for this reach and for the summit at Mauvages has never been more than barely sufficient, so that the whole question is again opened up, and it has been determined to give it a complete and satisfactory solution.

The summit reach upon the Marne-Rhine Canal at Mauvages, and the slope towards Toul as far as the Pagny reach, together with a length of 3 miles on the slope towards the Marne, are supplied exclusively from the head waters of two streams called the Ornain and the Meholle. According to calculations made at the time the canal was opened, based upon observations during the

dry season which occurred in June 1854, the volumes which these streams could be counted upon to furnish were :—

| | | | |
|---|---|---|---|
| The Ornain . . . . . | 9,540,000 | gallons per | twenty-four hours. |
| „ Meholle . . . . . | 660,000 | „ | „ „ |
| Total . . . | 10,200,000 | „ | „ „ |

which amount is exactly equal to the consumption on this part of the canal.[1] It was found, subsequently, that the Meholle is at times completely dried up, and that the volume of the Ornain may diminish to little over half that here supposed. This leaves a deficit of 5,500,000 gallons a day. Observations show further that the period of deficiency might reach six months, in which case a total volume of 1,012,000,000 gallons would be required. As it is impossible to construct reservoirs in the neighbourhood of the summit, the only way by which this supply can be obtained is by raising it by artificial means from some available source below. In all the schemes proposed for the complete solution of the problem, the supply for the summit at Mauvages is derived from the Pagny reach. The difference of level between them is 124½ feet, and the water is raised by steam engines situated at the village of Void. The volume of 1,012,000,000 gallons must therefore be added to the quantity supplied to the Pagny reach.

The amount of water supplied by the springs at Vacon was found to be sufficient at all seasons for the Pagny reach and for the descent towards Toul, although during five months in summer there was no surplus. The additional leakage caused by raising the level of the water is estimated at 2,200,000 gallons a day, which, in five months, amounts to 352,000,000 gallons. On the section of the new canal from the Pagny reach to the Meuse, the loss by leakage will be very great, on account of the nature of the soil. It is estimated at 250 gallons per lineal yard a day. This, with the amount required for lockage, gives a total of 484,000,000 gallons for the period of five months. After the canal reaches the level of the Meuse, use is made of a mill-pond near Commercy, in which the depth of water is sufficient, and part of the water in the pond is thus lost to the mills. As compensation 264,000,000 gallons are allowed to pass down the canal from the Pagny reach during this period. By the addition of these various items, the total quantity of water which has to be furnished to the Pagny

[1] *Vide* an article written by M. Malézieux in the 'Annales des Ponts et Chaussées,' 3rd series, vol. xi.

reach is found to be 2,112,000,000 gallons; and assuming that the whole of this amount has to be supplied during the five summer months, the volume required is 14,000,000 gallons a day, or 9,800 gallons a minute. It has been thought more prudent to call this 10,500 gallons.

The difference of level between the Meuse and the water in the Pagny reach is only 18 feet, and by ascending the river a few miles it would not be difficult to construct an aqueduct which would lead its water directly into the canal. Several schemes for effecting this were, in fact, drawn up before the construction of the Eastern Canal was proposed. The discharge of the Meuse, however, is known to fall below 12,000,000 gallons per twenty-four hours, as in the summer of 1870, so that its whole volume is insufficient for present requirements, and to draw from it would entail great expense in indemnities to the riparian owners of mills. It was then suggested that reservoirs might be established in the valley of the Meuse or of its tributaries, to store up and render the flood-water available both for the mills and the canal during the summer season; but suitable sites were only to be found far up the valley. The valley, almost from the source of the river, is cut through the Jurassic formation, in which many of the beds are extremely permeable, so that it would be difficult and expensive to make the reservoirs water-tight. It was also found impracticable to establish an adequate reservoir in the vicinity of the Pagny reach, and as no other choice was left, the Moselle had to be resorted to for the necessary supply. The volume is ample, but unfortunately its level is much below that of the Meuse. At Toul it is 130 feet 6 inches below the water in the Pagny reach.

A considerable amount of water-power is available at the locks along the Moselle immediately above Toul, and it has been decided to utilise this for the purposes of supply. Three pumping stations will be established near these locks. It is found from the data in regard to the volume of water in the canal and the fall at the locks, that 7,300 gallons per minute could be raised to the necessary level. This volume will be led by an aqueduct along the left bank of the Moselle and the right bank of the Ingressin, and will fall into the Pagny reach at the village of Foug, near its eastern end. The buildings in which the pumping engines are to be erected are close to the canal on the side next the river just above the locks, and the water is led to them by arched masonry conduits passing through the bank of the canal. The current produced in the canal by the water being thus drawn off is less

than ½ mile an hour. The pipes conveying the water up the slope on the left bank of the Moselle to the aqueduct are 4 feet in diameter, and cross the canal either on a bridge over the lock at its lower end, or by being laid under the canal. They ascend the line of steepest slope, except at the second station from which the pipe deviates to the right up the side of the valley in order to fall into the aqueduct below a siphon which occurs in this vicinity, and which would otherwise require to be of larger diameter.

The points at which the aqueduct is supplied divide it into three sections. In calculating its dimensions, the velocity of the flow is fixed at 1 foot per second. If it were less, the discharge would be liable to be much decreased by an accidental obstruction; and a greater velocity would necessitate a greater slope, and an increase of the height to which the water would have to be pumped in the first instance. The given discharge on each section was increased by one-third, and from it and from the velocity the sectional area was computed in each case. Assuming the side slopes to be 1½ to 1, the width of the channel and the corresponding depth of water can be determined, which will give a minimum value to the mean radius. The necessary longitudinal inclination was then calculated from the tables of Darcy and Bazin. It was found to be as follows:

| | |
|---|---|
| 1st section . . . . . | 35 in 100,000 |
| 2nd „ . . . . . | 20 „ 100,000 |
| 3rd „ . . . . . | 15 „ 100,000 |

The aqueduct is carried across the secondary valleys by inverted cast-iron siphons. The diameter of those on the first section is 2 feet, and of the two others which occur on the second section, 2 feet 7 inches. There is a short tunnel on the third section, through which the aqueduct passes under the village of Choloy. This tunnel is a circular brick conduit 6 feet 6 inches in diameter in gravelly clay. The water only occupies a depth of 4½ feet. The aqueduct passes over beds belonging to the Lower and Middle Oölite and to the Oxford clay. On the Oölite formation, it is in places lined with a layer of concrete to prevent leakage. With this precaution it is thought possible to reduce the loss to an average of 20 gallons per lineal yard a day. The aqueduct is therefore capable of conveying 6,900 gallons per minute to the Pagny reach.

It has been stated that the total amount of water required is 10,500 gallons a minute, and that after employing the whole

available water-power of the Moselle there still remain 3,600 gallons a minute to be furnished in some other way. The difficulties of obtaining a supply from the Meuse have already been explained, and although in general its basin is extremely unsuitable for the construction of reservoirs, it was found possible to establish one about 30 miles above Pagny in the valley of the Vraine, a stream falling into the Vaire, which is in turn a tributary of the Meuse. It could be placed partly upon the clays of the Lias, and partly upon the outcrop of the Lower Oölite. An embankment 52 feet high would retain a volume of 1,518,000,000 gallons. The reservoir can be filled by leading to it the water of a brook in the vicinity, by a tunnel 1,530 yards long, as observations show that the annual discharge of the brook is always superior to the volume contained in the reservoir. The embankment retaining the water is of earth, of which a most suitable quality is found in the immediate neighbourhood. It is protected on the inner face by a covering of masonry, built in steps so as to give a general slope of $1\frac{1}{2}$ to 1. The water when let out will follow the valleys of the Vraine, the Vaire, and the Meuse, of which the discharge will be sufficiently increased to allow of 3,600 gallons a minute being abstracted at Pagny during the summer months without encroaching upon manufacturing interests. During five months this amounts to 778,000,000 gallons, or only half the amount supplied by the reservoir; so that the loss occurring on the way down the river is amply allowed for. The water will be raised to the Pagny reach by steam-engines on the bank of the Meuse.

The Eastern Canal from Pagny to Verdun is constructed as a lateral canal to the Meuse, as the river is small and the width of the valley affords every facility for this system. Immediately on leaving the Pagny reach there is a lock upon the new canal, and the following reach continues along the hillside on the right bank of the Meuse. The soil consists of angular pebbles, varying from the size of a pea to sand; but the quantity of sand is not sufficient to fill the interstices between the pebbles. The formation belongs to the Coral Rag, and allows much water to escape; especially as it was necessary to form one side of the canal in embankment, to separate it from an old borrow-pit. In making this embankment the natural soil was mixed with one-fifth to one-fourth of vegetable earth; but the loss of water, ascertained by gauging the inlet from the Pagny reach, still amounts to $40\frac{1}{2}$ gallons per lineal yard in twenty-four hours, and the water can be seen bubbling up in the bottom of the borrow-pit. Fine sand

is now being thrown in to stop the leakage. Beyond the next lock the soil becomes clayey, and this, with the lowered level, renders the leakage very slight.

After crossing the railway from Paris to Strassburg the canal follows the right side of the valley of the Meuse, and for a short distance keeps above the line to which floods extend. It then descends, and crosses the meadows forming the bottom of the valley, and enters the head of the mill-pond of Commercy. In crossing the valley the tow-path is placed at the natural level of the ground, so that the flow of the river in time of flood may not be interfered with. The summer level of the Meuse and of the water in the canal is 3 feet below this; and by the time the water rises to the level of the tow-path the navigation has in any case to be suspended, on account of the current in the parts of the river made use of. The interruption thus occasioned usually lasts about a fortnight. In excavating in this part of the valley there is, first, a depth of about 3 feet of silt, which has been deposited by the river in time of flood, and which now forms a moderately stiff blue clay. Below this, gravel is met with, which extends to an indefinite depth, and is always full of water up to the level of the river. In making the cutting for the reach which lies across the valley, it was first taken down to the surface of the water in the gravel along its whole length. Below this it is being completed in short lengths, in which the water is kept down by pumping. For this purpose a double hand-pump, raising about 200 gallons a minute, has so far been sufficient.

Between Commercy and Lérouville the railway from Paris to Strassburg skirts the left side of the valley, and sometimes obliges the canal, which also follows the left side, to take the channel of the river. At Lérouville there are extensive quarries of white crystalline limestone belonging to the Middle Oölite, from which all the ashlar for the locks, bridges, and other structures, as far as Charleville, and even beyond it, has been obtained. It can be had in large and perfect blocks, and is easily cut. From Lérouville a line of railway has recently been constructed, which follows the valley of the Meuse into Belgium. It is kept along the left bank as far as Sedan, and both it and the canal are on the same side for about 5 miles below Lérouville. Here there is a long detour on the Meuse, caused by a spur extending from the hills on the west side of the valley. The railway, which has as yet only one line of way, crosses this ridge in a cutting, about 45 feet above the level of the river; and the canal will pass under the railway in a tunnel. It is being constructed by making an open cutting across

the ridge, which is of limestone, in which the arched roof of the tunnel will be built, the railway being meanwhile diverted. When completed the cutting will be filled in again. On reaching St. Mihiel the canal enters the river, passes under one of the arches of an existing stone bridge, and below the town is continued as a lateral canal all the way to Verdun.

The passage of Verdun presents several points of interest. The town occupies the whole width of the valley, here very narrow, and the fortifications with which it is surrounded extend to the hills on each side. The river passes through a series of arches, resembling a bridge in appearance, connected at each end with the general line of the fortifications. By a suitable arrangement these arches can be stopped, causing the river to inundate the whole valley for miles above, and so to prevent the approach of an enemy. The canal passes through the fortifications by a tunnel now completed, which can be stopped. This is done by placing across it a double barrage of beams, laid horizontally, and retained at their ends by grooves in the side-walls. By filling the interval between them with earth a cofferdam is formed, which reaches almost to the roof of the tunnel. The side-walls extend vertically down from the springing of the arch, and the tow-path, which is of wood, is supported by timber uprights, so that it can be removed in case of war. This disposition is favourable to the passage of the boats, as it increases the sectional area of the water-way, and so allows the water to pass around the sides of the boat much more readily. It was proposed at first to place a lock in the tunnel in order to save masonry; but as this would have required the foundations to be carried down to a much greater depth, a matter of difficulty in so confined a position, and as it would also have caused inconvenience in the working of the lock, it was decided to place it immediately outside the tunnel, at the lower end. In constructing the tunnel an open excavation was made as far as the springing of the arch; and below this, timbered trenches were carried down on each side, in which the side-walls were founded. The earth left between them was used to support the centering, and when the arch was completed it was removed and the paving of the floor put in. None of the three bridges in Verdun permitted the passage of the canal. They are now replaced by new bridges, two of stone and one of iron. In some cases the existing piers have been made use of. In the middle of the town, the Meuse meets the canal St. Vanne, which is the tail-race of some mills; and it here makes an abrupt turn quite unsuitable for a navigable channel to follow. To round off the

sharpness of the angle, and to lay out a curve among houses crowded together to the edge of the water, was attended with difficulty. The intersection of the curve with each of the property lines was determined, and by joining these points a straight front was given to each, while the curve on the outer edge of the tow-path was made continuous. All these works are now completed. They have been carried out in a most thorough manner, and the improvement to the town itself and to the appearance of the river is marked. The level of the water in the town is raised by a barrage situated about ½ mile below, near the village of Belleville, after which it is named. It may be taken as a type of all the barrages being erected along the Meuse, as the system is the same throughout. (Plate 8, Figs. 7, 8, and 9.)

Between Verdun and Sedan the system of canalization is modified to adapt it to existing works. At each of the towns, which occur at intervals of about 10 miles, there is a mill-dam increasing the depth of the water; and to pass these there are the side-cuts and locks constructed since 1861. Although the depth of water in them is only 3 feet 11 inches, they are taken advantage of as far as possible; and in all cases the mill-ponds form a most convenient way of passing the towns. They sometimes extend as much as 2 or 3 miles up the river. Where the natural features of the valley admit, a barrage is constructed below the dam, to increase the depth of water on the lower lock-sill. From this to the head of the next mill-pond the canal leaves the river, as its depth is often less than 2 feet, and skirts its right bank to avoid the railway on the other side. At Sedan the existing side-cut is not made use of, as the surrounding mills render the circulation upon it inconvenient. The town consists of two parts, which are connected by a long stone bridge, passing over a meadow which is covered with water when the river is in flood. In this meadow the new cut has been made, and the lock on it has been placed under the bridge, as it is necessary to replace the part over the canal by an iron span; a saving of masonry has been effected by carrying up the side-walls of the lock to form the abutments. Between Sedan and Charleville the system of dams is more employed; and by means of them the water in the river is sufficiently raised to enable the canal to use its channel for three-fifths of the total distance. The dams, which can be entirely removed while the river is in flood, are placed about 3 miles apart, and raise the water to a height averaging 6 feet above summer level.

Below Charleville this system is carried out in a most complete

way, as the valley of the river is particularly adapted for it. The general fall of the river is about 2 feet in the mile, and the dams are placed along it at an average of 3½ miles apart, giving 6 feet 8 inches as the mean height to which they raise the water. The whole fall, however, is not taken up by them, as the raised level of the water does not necessarily extend to the foot of the barrage above, although it is usually made to do so. The dams are passed by means of side-cuts called "derivations," usually less than 1,000 yards long, as the valley is too narrow in most cases to allow of their being extended further. In time of flood the water rises 18 feet above its summer level,[1] and the bank of the derivations on the side next the river is carried up to this height to prevent the destruction of the earthwork which would result from the water running over it. The locks are always placed in these derivations, and are near their lower end, the side-walls of the head-bay being raised to meet the earthwork. They are built with a double lift-wall, as in the case of those further up, and the head-gates come up to flood level also, to prevent a current from passing through the derivation. This increases their weight, and so makes the lockage a little more troublesome, but the difference is unimportant. The side-walls of the lock-chamber and the lower gates are only a few inches above the level to which the water is raised by the dam; for when the level of the river rises above this after the dam has been removed, the circulation is no longer possible, and the head-gates have to be kept shut. In all cases the earthwork is faced with a rock protection as far up as the water ever rises. In the longer derivations a guard-lock is placed at the upper end, so that they can be used as harbours of refuge by boats during floods, or while ice is in the river.

The dams are all similar to each other, and, as shown in Plate 8, Fig. 7, consist of a set of sticks called "needles," placed side by side, and extending across the river. The needles are 2½ inches square, 14 feet long including the handle, and are slightly inclined up-stream. They are supported by light wrought-iron frames placed parallel to the current, and connected above by cross-bars, against which the upper ends of the needles rest. They serve also to support a light foot-bridge, from which the needles can be inserted or removed. The frames are 3 feet 7 inches apart, and are placed on the top of a masonry foundation which extends across

[1] The water rose to this height all along the river in 1846. The greatest flood on record, which occurred in 1784, attained a height of 23 feet.

the river. (Plate 8, Fig. 8.) The dam is divided into three equal passes by two piers resting upon the masonry foundation, of which one serves as a fish-ladder, as shown in Plate 8, Fig. 10. The horizontal bar composing the lower side of the frame can turn in iron sockets, anchored firmly to the masonry, and when the cross-bars and needles are removed, the frames can be folded over flat on the top of the masonry. This system of dam was invented by M. Poirée, and was tried successfully in 1834 at Basseville on the Yonne. It has the advantage of enabling the height of the water to be regulated with great precision, by the removal or replacement of some of the needles. The water is not permitted to flow over it, as this would render the foot-bridge impassable; and considerable watchfulness is necessary in case of floods after storms. At each dam there is a house occupied by the men who attend to the lockage and watch the water-level; a line of telegraph unites these houses, whereby notice can be given from above of the time at which floods may be expected to arrive. The cross-currents, which are occasioned by the partial removal of the needles, render it inadvisable to place the locks immediately at the end of the barrage, as it would be difficult for the boats to enter the locks either from above or below. This is the principal reason for the construction of derivations for passing them. The movable part of the dam is in all cases of the same height, so that the frames and needles may be identical all along the river. The level of water required is obtained by adjusting the height of the masonry, which is always somewhat above the bottom.

This system is convenient for a river of the size of the Meuse at Charleville; but in Belgium, where its volume becomes greater, it has been found necessary to make part of the dam in such a way that storm-floods may flow over it. Two of the passes are constructed according to the system of M. Chanoine, in which the water is retained by wooden shutters, framed like a door. These are supported by iron trestles placed upon a masonry foundation, whose coping is considerably above the bottom, in order that the height of the shutters may not be too great. They are so arranged that they can be laid back upon the top of the masonry. To gain access to them it is necessary to have a foot-bridge on the up-stream side, supported by frames which can also be folded over upon the masonry, and which are similar to those used for the needle barrage. This increases the width of the masonry foundation, and makes this kind of dam more than twice as expensive as the other, in which the frames serve the double purpose. In the remaining pass, the masonry is placed at

the level of the bottom, so that by opening the dam the pass can be used for navigation at certain seasons of the year. It is closed by needles, as the height of the movable part is necessarily considerable, and they are much easier to handle than the shutters. The masonry, being at the level of the bottom, is liable to be encumbered by pebbles and stones, which might seriously interfere with the working of the shutters, for the ironwork connected with them is somewhat complicated, and movable parts occur close to the surface of the masonry. Shutters of this kind have been used to close navigable passes, but only in rivers in which the current is gentle and the bed is of fine sand or earth.[1]

The above-mentioned combination is now used in Belgium, and seems to be admitted to be the most satisfactory for large rivers, after the experience of a number of years. It also has the advantage of allowing the lock to be placed in the river next to the navigable pass, as the overflow takes place at the other side of the river; as the water rises, its level is regulated by manipulating the shutters, until the whole dam has to be laid down.

The bed of the Meuse below Charleville consists of sand and gravel, below which the rock is found at no great depth. The masonry foundation is, in most cases, built upon the rock; but where the rock is too deep, a layer of concrete is laid upon the gravel. In constructing a dam, a cofferdam is built from the shore half way across the river, enclosing a space adjoining the shore which can be pumped out. The disposition of the cofferdams employed will be seen on referring to Plate 8, Fig. 10. Considerable caution is required in their construction as the scour is often great. When the current is very strong, a dyke of loose stones is first formed across the middle of the enclosure to break its force. The stones can thus be used subsequently in the masonry. After the first half of the masonry is completed, an enclosure is built out from the opposite shore, which has to cross a part of the masonry already built. The water then flows over the top of the masonry, so that the level of the water is higher than during

[1] For the greatest height of water which shutters have yet been employed to retain, see 'Nouvelle passe navigable établie en 1870 dans le barrage de Port-à-l'Anglais,' in the 'Annales des Ponts et Chaussées,' 2e Semestre, 1873. Also two pamphlets by M. Boulé entitled 'Notice sur une nouvelle passe navigable établie en 1870 dans le barrage de Port-à-l'Anglais,' and 'Mémoire sur les barrages mobiles à forte chûte.' (Dunod, 1876.) (*Vide* Minutes of Proceedings Inst. C.E., vol. xliv. p. 268). A general description of the different kinds of dams will be found in an article by Lagréné, 'Etude comparative sur divers systèmes de barrages mobiles' in the 'Annales des Ponts et Chaussées,' 1er Semestre, 1866.

the construction of the first part. It is usual to extend the first enclosure rather more than half way across the river on this account. The barrages are sometimes placed where the river is divided into two branches by an island. Their construction is then easier, as the two parts of the river can be dealt with separately. When the water within the enclosure has been removed by pumping, the work is set out with extreme nicety, as is essential when ironwork, consisting of movable parts, has to be placed upon it. The principal reason for the width of the river being divided into sections, by the construction of piers, is that any slight error in the spacing of the frames may be allowed for. If the sections were too long it would become difficult to place the cross-bars which connect the frames at the top, and the stability of the barrage would be impaired. The enclosure is made wide enough to include the sloping aprons (Fig. 8), which are built of dry rubble, and connect the top of the masonry with the natural bed of the river above and below; they are hand-laid, and the surface stones require to be fitted with care. The apron on the lower side of the barrage is the part of the work most liable to yield, as during the construction of the second half of the barrage it is exposed to a violent current. The barrage of St. Joseph, near Fumay, is the highest upon the river, and is the only one in which the summit of the masonry is above the natural summer level of the water. The surface of the lower apron was grouted with cement; but notwithstanding, a considerable portion of it was carried away during the construction of the second part of the work. It is to be observed, however, that this does not compromise the solidity of the masonry foundation of the barrage itself, unless the damage extend so far as to allow it to become undermined. It is not difficult to replace the stone thus washed away; though it has been found, in more than one instance, necessary to do this several times before the slope of the surface became gentle enough to resist the erosive action of the water.

Two tunnels on the river below Charleville require to be enlarged. The first, at Fumay, has been heightened and widened in order to allow of the construction of a tow-path along one side. The rock is solid, and no masonry is required. The other tunnel is just above Givet. The derivation of which this tunnel forms a part, cuts off a long bend of the river, and upon it there are two locks, as the fall on the river is considerable. One of these locks is situated above the tunnel, which is remarkable, as it serves merely to increase its length and the difficulty of construction. The part of the derivation below the tunnel is not long, but

ere would be no inconvenience in the locks being placed end end. However, this cannot be altered now, and to obtain as uch advantage as possible from the existing works, a lock has ill to be placed above the tunnel. It was first proposed to make e of the existing lock; but this plan would render it necessary heighten the tunnel, to secure sufficient head room above the ised level of the water, which would be difficult as the rock in uestion is much jointed and often treacherous. It was found referable to deepen it on the floor, and to construct a new lock ith a greater fall above. The roof has never been in a satisctory state, and a masonry lining is now being put in along the reater part of its length. The lock below the tunnel will continue be used.

Below Givet there is one derivation before reaching the frontier. he lock on it is made as long as those in Belgium, and like em is built without a lift-wall.

In conclusion it may be observed that the Eastern Canal, when nished, will be one of the finest lines of water-communication in rance.

This communication is accompanied by numerous drawings, from hich Plates 7 and 8 have been compiled.

No. 1,613.—"Draining and Improving 1,500,000 acres of Desert Land."[1] By GEORGE WILSON, M. Inst. C.E.

IN the west of France, close to the important town of Bordeaux, there existed, previously to the year 1850, an immense territory of uninhabited desert lands, comprising nearly 2,000,000 acres superficial area, and designated "Les Landes de Gascogne." The territory is triangular in shape. The base, commencing at a point close to the mouth of the river La Gironde, extends to the south of that river along the shores of the Bay of Biscay for a distance of about 140 miles; while one of the sides, passing by and about 5 miles distant from Bordeaux, is approximately parallel to the course of the river La Gironde for a distance of about 120 miles from its mouth.

The desert lands of this territory resembled a vast and nearly horizontal plain at an average altitude of about 330 feet above the level of the sea. The surface of the ground consists of poor sandy soil, without any trace of clay or calcareous matter in its composition, varying in depth from 12 to 20 inches. Under the surface soil there is an impermeable layer of silicious sand, agglomerated by vegetable matter, varying in thickness from 16 to 20 inches, forming a sort of organic cement, which is known in the country under the name of "alios." The substratum under this layer of "alios" consists of compact white sand impregnated with water. There does not exist on the surface of the plain any spring, nor is there any trace of water during the summer. During the winter, however, previously to the execution of the drainage works, the abundant rain of that coast, experienced for more than six months, falling on the plain, could neither flow off its surface, nor percolate sufficiently through crevices of the impermeable layer of alios into the substrata. The water remained stagnant until it was evaporated by the heat of summer. Thus the constant inundation during the winter, and the dryness of the hot sandy soil during the summer, rendered the ground sterile for any kind of cultivation, and

[1] This Paper is based on a memoir by M. Chambrelent in the "Annales des Ponts et Chaussées," August 1878, p. 157.

In the Minutes of Proceedings Inst. C.E., vol. xvi., p. 378, Mr. F. A. Conder, in a Paper descriptive of the Permanent Way of the Bordeaux and Bayonne railway, directed attention to the draining and improving the Landes.

extremely unhealthy for the inhabitants and for animals to exist or work on it.

Previous to 1850, several attempts had been made, and much money expended, in endeavouring to improve and drain portions of this desert, all of which, however, resulted in failures, and caused the impression to prevail, that the soil was of little value, certainly not worth the expenditure necessary to drain and improve it for the purpose of cultivation. In 1849 a report appeared by M. Chambrelent, Ingénieur en Chef des Ponts et Chaussées, describing the results of complete studies, surveys, levels, borings, &c., of the desert, which he was officially commissioned to carry out, extending over seven years. From these studies the exact physical features of the desert were developed, and at once indicated the mode of improving and rendering it profitable for cultivation. It was shown that, upon the whole extent of the apparently-horizontal plain, there exists from the summit towards the valleys extremely regular slopes, but so small that the least irregularities of the ground hinder the water from following the normal declivities.

The average inclination of the ground is about 1 in 1,000, but in some parts it does not exceed 1 in 2,000, and continues always in the same directions towards the valleys without any noticeable change or break. The small irregularities on the surface, which hinder the flow of the water, are never more than 12 to 16 inches above or below the normal slopes of the plain. Therefore a drain 20 to 24 inches deep, with its bottom parallel with the general slope of the ground, can be made along its entire required length without necessitating a cutting of more than from 24 to 28 inches, in order to allow the water from rainfall to pass perfectly away. Moreover, a ditch extending along such sandy permeable ground will drain the surface to a considerable distance on each side of it, and as its average inclination will be about 1 in 1,000, the water will percolate slowly and regularly to it without causing injury to the sides. In consequence of the permeability of the surface soil very few drains are required.

It had been noticed that there existed in a few isolated places of the desert clusters of fir trees, locally termed "Pignades," which flourished remarkably well; also that the ground at such places was slightly higher than the normal inclination of the plain, and was therefore drained naturally, and that both the surface soil and the subsoil where the trees flourished were physically and chemically, as shown by analyses, similar to the ground of the entire plain. It was thus evident that the desert only required to

be properly drained in order to cultivate it for a forest, and for it to produce trees similar to the clusters or "Pignades" actually growing. There were, however, at the time, numerous objections against these deductions as to the practicability of the drainage and improvement scheme. It was contended that drains cut through such sandy ground would soon be silted up, from the effects of the wind on the sandy plain, and be trodden in by cattle, or destroyed by the drainage water percolating through their sides. A further objection was urged, that the drains would have to be made of such great lengths that the water could not be caused to flow along them to the distant valleys.

To meet these objections, and to test the practicability of the scheme, it was decided to make a trial. A superficial area was selected of about 1,250 acres of the desert, nearly on the summit, and in the middle of one of the most sterile parts, being in every sense under the most unfavourable conditions for draining the soil. At the time of commencing operations the ground was covered with stagnant water, so that it was necessary to move about on the stilts used in the country. The effects of the drains was immediately satisfactory. The ground was so well drained that during the heaviest winter rain no stagnant water existed on it, and the water flowed away abundantly and with great regularity. All the rain water percolated immediately through the soil into the drains, and none was noticed to flow along the surface. At present, although it is more than twenty-seven years since these drains were executed, yet such is the slowness and regularity with which the water percolates into and along them, that they have not silted up nor have their sides been injured.

Shortly after this trial ground was drained, it was sown with fir seeds and acorns, and the results were so satisfactory that in the following year numerous proprietors of portions of the desert carried out similar works, and obtained an equal success; and in less than five years an area of more than 50,000 acres was drained and cultivated for forests. As regards the first sowing on the trial ground, in five years fir and oak trees had grown over the whole area to a height of nearly 12 feet, and each tree was about 12 inches in circumference above the ground.

After proving the practicability of draining the territory, the important question arose as to the possibility of obtaining wholesome drinking-water for the inhabitants. There are no springs of water, and the potable water hitherto obtained was derived from wells dug through the "alios" to a depth of about 4 feet below the surface of the ground. The bad quality of the water caused

even worse fevers and other diseases than the unhealthiness arising from the marshy nature of the soil. Borings were made to various depths below the surface through the "alios" into the substratum of compact white sand, and on analysing the water, it was shown that the water increased in purity with the depth. At a depth of about 13 feet from the surface the water was practically fit for drinking purposes provided it was caused to filter at the bottom of the well, by ascending through an artificial bed of broken calcareous small stones and clay gravel. Wells have therefore been sunk, wherever required over the territory, to a depth of about 13 feet, and the sides built with masonry laid in cement so as to be perfectly and permanently watertight. The water can thus only ascend the bottom of each well after filtering through an artificial layer of broken stones (generally the *débris* from dressing the stones for lining the well) and clay gravel. The organic matter found in the water of the old wells was as much as $\frac{1}{29412}$ part by weight, or about 2·4 grains per gallon, while the water drawn from the new wells only contained organic matter equal to $\frac{1}{500000}$ the weight of the water, or 0·14 grain per gallon.

Extensive portions of the deserts belonged to one hundred and sixty-two communes, and were so intermingled with the property of private owners as to be a hindrance to the latter carrying out their drainage works effectually until such portions were drained. To facilitate and ensure the communal possessions being drained, and to construct the necessary roads of communication over such a large territory, the Government, in 1857, made the following special laws:—"The waste lands of the communes of the two departments, La Gironde and Les Landes, shall be drained and improved at the expense of the communes. In case of inability, or refusal on the part of the communes, to carry out these works, the same shall be done at the expense of the State, to be repaid the advance made in principal and interest out of the produce and cultivation." The law also provided for the construction of the roads of communication by the State.

So soon as the above law was promulgated, a general plan was prepared for draining the waste lands belonging to the communes, comprising about 720,000 acres, irrespective of about 864,000 acres belonging to private individuals, which remained to be drained. The plan comprised the execution of the principal canals necessary for receiving and carrying away the water flowing from the land drains. The fixing of these canals over ground almost flat presented many difficulties. The whole country had to be again carefully levelled, which showed that the inclination of some portions of the

plain was not more than 1 in 2,000. The inclinations of the canals had to be calculated in such a manner so as to be sufficient for the proper drainage of the water resulting from a varying rainfall, and yet not such as would cause a current injurious to the canals constructed through ground of such a sandy nature. The main canals in the department of La Gironde were 13 feet to 16·4 feet wide at the bottom, and their total lengths amounted to 1,365 miles. The canal between the pools or lakes Lacanau and Langourarde, bordering the sand dunes on the coast (which had to be constructed for a distance of $\frac{5}{8}$ mile through a marsh always covered with water), is 39·4 feet wide at the bottom, 6·3 miles in length, and has an inclination of 1 in 4,000; while the canal made between the pools or lakes d'Hourtins and Lacanau, through the middle of a marsh for a distance of 5·2 miles, is 23 feet wide at the bottom. The two last-mentioned canals receive the drainage water of 200,000 acres superficial area.

In 1865 the drainage works of the communal lands were completed at a cost of about 1*s.* 10*d.* per acre drained. Out of the total area of communal lands comprising 720,000 acres, 466,000 acres have been sold from time to time to meet expenses, so that the funds of the State were not drawn upon. Some portions, previous to being drained, were disposed of for a sum of £537,278, which sum was applied for the following purposes:

| | £. |
|---|---|
| Draining | 35,739 |
| Sowing land with seed | 27,272 |
| Construction of new and restoration of old churches | 95,660 |
| Construction of new and restoration of old parsonages | 27,082 |
| Construction of new and restoration of old town-halls and school-houses | 65,455 |
| Subscriptions, subventions, and allowances for the construction of roads | 79,489 |
| Various expenses—construction of wells, removing cemeteries from market towns and villages | 32,471 |
| Communal funds invested in rentes of the State | 174,110 |
| Total | 537,278 |

With the exception of lands situated in various parts of the plain, amounting to about 70,876 acres, respecting which there are, amongst other causes, disputes as to the boundaries, the whole of this formerly desert territory is now under forest cultivation, consisting mainly of fir trees. Oak trees, although growing equally well, and more profitable in the course of time, are nevertheless more expensive to cultivate during the first few years, and conse-

quently the ground has only been to a limited extent used for their cultivation. Everywhere and in every respect the results of forest cultivation are highly satisfactory, showing the most vigorous vegetation and growth, and developing equally well each successive year. The only cause for anxiety arises from accidents and losses by fire. From 1865 to 1870 serious losses occurred from that cause, destroying 25,000 acres of forest. Since 1870 such fires have somewhat diminished, and the Government is adopting special measures to prevent these disasters. It might be considered that the production from forests, comprising an area of 1,500,000 acres, would so much diminish the price of timber that profitable markets could not be found. Time and experience have, however, proved that no fears need be entertained on this question. Each year the purposes and appliances for the production of such forests increase, and the selling prices augment accordingly. The timber of these forests is not only sold in France, but is exported to England and Scotland, and even to America and Spain. In England large quantities are sold for props, &c., used in coalpits, in pieces each about 6½ feet long and 3½ inches in diameter. The younger trees and branches are sold for the fuel throughout France. Large quantities are used for making wine cases and barrels. A mill has recently been successfully set to work, making 1,000 tons of pulp per annum, for the manufacture of paper direct from the fir tree, which industry it is anticipated will rapidly increase, inasmuch as the pulp produced is of brilliant whiteness. Another industry is being developed in manufacturing, by the aid of recent discoveries, rectified essence of turpentine from fir trees, for the purpose of illumination, the light produced being considered superior to, and more economical than, that from any of the oils or from petroleum. The above are some of the objects for which the production of the forests are used up to the first twenty-five years of their growth, after which the timber is sufficiently large to be applied to more extended purposes, such as general carpenters' work, sleepers for railways, telegraph posts, &c. For the latter purpose large quantities are already being used in France, and exported to Algeria and Spain. In 1877 the timber on a plot of ground of 11 acres superficial area, which was in its twenty-eighth year of growth, was sold for £192, equal to £17 9*s*. per acre; but this plot of timber was favourably situated for being carried away.

At an average age of thirty years the present forests, comprising 1,514,110 acres, are estimated to produce timber worth at a minimum price £9 15*s*., and in seventy years £32 10*s*. per acre, respec-

tively equivalent to a total value of about 14¾ and 49¼ mil
pounds sterling for the produce of those lands which were i
a desert. This valuation is based on the probable casual
fire, and would consequently be considerably higher if the
losses from that cause did not exist.

Independently of these satisfactory results, the drai
the desert, and the construction of deeper wells for the su
wholesome drinking-water, have changed the district into
the healthiest in France; whereas previously, the inh
suffered constantly from fevers and other fatal diseases,
the death-rate to be exceedingly high.

The maintenance of the main canals, of a total length o
miles, is under the inspection of the administrations of the
partments, La Gironde and Les Landes, who give orders to the
of the communes and proprietors of lands bordering the ca
clean them out when necessary, or to remove impediments i
from whatever cause, inasmuch as it is of importance that
of such great lengths, small inclinations, and dug in san
should always be maintained in good order.

## No. 1588.—"On the Slopes of Cuttings." By WILFRID AIRY, B.A., M. Inst. C.E.

THE object of this Paper is to determine the proper shapes to be given to the slopes of cuttings in different kinds of ground. The Author has long been convinced, that a great waste of land and labour has resulted from the ordinary practice of dressing slopes to a straight batter; but it is only recently that he has been able to bring the subject within the range of mathematics, and to determine the constants required for the practical use of the formulæ. So far as the Author is aware, no published investigation deals with the subject of the stability of earthwork in compact natural ground. The investigations in engineering educational books refer almost entirely to dry disintegrated soil, which is a theoretical state of the ground applicable only to loose earth piled against a retaining wall.

When a cutting has been made in compact natural ground, two kinds of forces tend to prevent the slipping-in of the sides of the cutting, viz., cohesion and friction. Cohesion is the intimate union of the particles which form the mass, and is due to the circumstances of pressure, &c., under which the ground was originally formed; as also to the presence of cementing materials, such as iron, alumina, &c. The degree of cohesion in different kinds of ground varies largely. In clean sand it is extremely small, while in compact clay and gravel the cohesion may amount to 800 lbs., or more, per square foot of section. The average cohesion of strong brick loam is about 168 lbs. per square foot. The degree of cohesion is much affected by the quantities of moisture in the ground at different times, especially in the weaker kinds of clay. The cohesive force due to any given section of a mass of compact natural ground depends only on the area of the section and on the co-efficient of cohesion.

Friction is the force which comes into play to prevent the movement of a mass that would otherwise slip down after overcoming the forces of cohesion. It acts conjointly with those forces to prevent movement. The co-efficient of friction varies extremely for different kinds of ground. For gritty soils, and for compact loamy clays, the co-efficient of friction is generally greater than 1, while for greasy shaly clays, the co-efficient is as small as 0·36. Friction, like cohesion, is affected by moisture, especially in clay soils. The

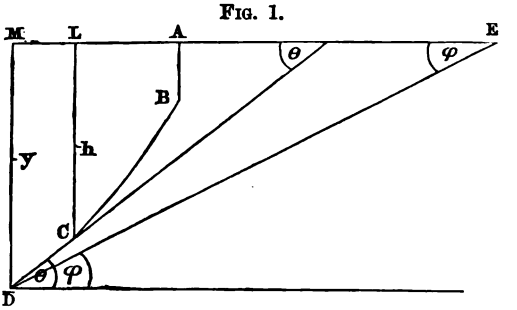
nature of the force is wholly different from that of cohesion, as it is independent of the area of the section, and depends only upon the weight of the mass which tends to slip, the inclination of the plane of section to the horizontal, and the co-efficient of friction.

In all cases of compact natural ground, cohesion and friction act simultaneously to prevent the movement of any part of the mass; but to introduce their joint effect into a mathematical expression, it is essential to apply their co-efficients separately. In the majority of deep cuttings, the ground varies considerably at different depths, and it would be incorrect to apply the same co-efficients of cohesion and friction for the whole of the mass. But for more uniform ground, the co-efficients may be considered as constant throughout the mass, and the curve of equilibrium may be calculated. It will afterwards be possible to lay down general rules for the shapes of slopes in ground of varying character.

To determine the minimum curve of equilibrium of a slope in ground of uniform character throughout.[1]

Let $\gamma$, $k$, $\mu$, be the co-efficients of weight, cohesion, and friction of the ground. Suppose that the curve of equilibrium has been determined step by step, from the top to a depth ($h$) from the top, and let A B C be the curve so determined (Fig. 1). It is required to know what is the inclination ($\theta$) of the curve of equilibrium for the next small portion, C D, of the curve, of which the point D is at a depth ($y$) from the top. Draw the straight line D E, inclined at an angle ($\phi$) to the horizontal, and consider the conditions of equilibrium of the mass A B D E A of the ground.

FIG. 1.




Let (W) be the weight of the mass A B D E A, and (I) the resultant tendency of the mass to slip down the inclined plane E D.

[1] By the minimum curve of equilibrium is meant the curve which ensures the stability of the slope with the least possible amount of excavation.

The force which urges the mass down the plane E D is the portion of the weight resolved parallel to E D, or $W \times \sin \phi$. The forces resisting motion down the plane E D are (1), the friction due to the pressure of the mass A B D E A, or $\mu$ W $\cos \phi$; and (2), the cohesion along E D, or $k \times DE = k \frac{y}{\sin \phi}$.

Therefore the resultant tendency to slip, I, is—

$$I = W \sin \phi - \mu W \cos \phi - k \frac{y}{\sin \phi}.$$

But $W = \gamma \{\text{area E D M} - \text{area C M} - \text{area A B C L}\}$,

$$= \gamma \{\tfrac{1}{2} y^2 \cot \phi - \tfrac{1}{2}(y^2 - h^2) \cot \theta - \text{area A B C L}\},$$

or $$W = \gamma \tfrac{1}{2} \{y^2 \cot \phi - (y^2 - h^2) \cot \theta - A\}.$$

(The area A B C L $= \frac{A}{2}$ is a known quantity, since the curve has been constructed as far as the point C).

$$\therefore \quad I = \gamma \tfrac{1}{2} \left\{ y^2 \cos \phi - (y^2 - h^2) \cot \theta \sin \phi - A \sin \phi - y^2 \frac{\cos^2 \phi}{\sin \phi} \cdot \mu \right.$$

$$\left. + (y^2 - h^2) \cot \theta \, \mu \cos \phi + A \mu \cos \phi - \frac{2 k y}{\gamma \sin \phi} \right\};$$

but $$\frac{\cos^2 \phi}{\sin \phi} = \frac{1 - \sin^2 \phi}{\sin \phi} = \frac{1}{\sin \phi} - \sin \phi,$$

$$\therefore \quad I = \gamma \tfrac{1}{2} \left\{ y^2 \cos \phi - (y^2 - h^2) \cot \theta \sin \phi - A \sin \phi - y^2 \mu \frac{1}{\sin \phi} \right.$$

$$\left. + y^2 \mu \sin \phi + (y^2 - h^2) \cot \theta \, \mu \cos \phi + A \mu \cos \phi - \frac{2 k y}{\gamma \sin \phi} \right\},$$

or $$I = \gamma \tfrac{1}{2} \left\{ \cos \phi \, (y^2 + \overline{y^2 - h^2} \cot \theta \, \mu + A \mu) \right.$$

$$\left. - \sin \phi \, (\overline{y^2 - h^2} \cot \theta + A - y^2 \mu) - \frac{1}{\sin \phi} \left( y^2 \mu + \frac{2 k y}{\gamma} \right) \right\}.$$

This is the tendency to slip down the plane E D inclined at an angle ($\phi$) to the horizontal. In order to determine the maximum slipping tendency of the ground, put $\frac{d I}{d \phi} = o$. The resulting equation will give the particular value of ($\phi$) for the plane down which the slipping tendency is greatest.

$$\frac{d I}{d \phi} = \gamma \tfrac{1}{2} \left\{ - \sin \phi \, (y^2 + \overline{y^2 - h^2} \cot \theta \, \mu + A \mu) \right.$$

$$\left. - \cos \phi \, (\overline{y^2 - h^2} \cot \theta + A - y^2 \mu) + \frac{\cos \phi}{\sin^2 \phi} \left( y^2 \mu + \frac{2 k y}{\gamma} \right) \right\},$$

and the value of $(\phi)$ which makes (I) a maximum will be given by the equation

$$o = -\sin\phi\,(y^2 + \sqrt{y^2 - h^2}\cot\theta\,\mu + A\,\mu)$$
$$-\cos\phi\,(\sqrt{y^2 - h^2}\cot\theta + A - y^2\mu) + \frac{\cos\phi}{\sin^2\phi}\left(y^2\mu + \frac{2ky}{\gamma}\right).$$

Dividing out by $\cos\phi$, putting for $\frac{1}{\sin^2\phi}$ its equivalent $\frac{1+\tan^2\phi}{\tan^2\phi}$, and reducing

$$o = \tan^3\phi + \frac{\sqrt{y^2 - h^2}\cot\theta + A - 2y^2\mu - \frac{2ky}{\gamma}}{y^2 + \sqrt{y^2 - h^2}\cot\theta\,\mu + A\,\mu}\tan^2\phi -$$
$$\frac{y^2\mu + \frac{2ky}{\gamma}}{y^2 + \sqrt{y^2 - h^2}\cot\theta\,\mu + A.\mu}.$$

This equation will give the value of $(\phi)$, which, substituted in the expression for (I), will give the maximum slipping tendency at the point D. If this be supposed done, and there be put $I = o$, an equation will be obtained for the value of $(\theta)$, which makes the maximum slipping tendency at D equal to zero. But on account of the complicated nature of the equations, it is impossible to eliminate $(\phi)$, and to obtain a single equation for the determination of $(\theta)$. Hence the equations must be solved in numbers by trial, and the problem is resolved into the determination of $(\theta)$ and $(\phi)$ simultaneously from the two equations.

$$(\alpha)\quad o = \cos\phi\,(y^2 + \sqrt{y^2 - h^2}\cot\theta\,\mu + A\,\mu)$$
$$-\sin\phi\,(\sqrt{y^2 - h^2}\cot\theta + A - y^2\mu) - \frac{1}{\sin\phi}\left(y^2\mu + \frac{2ky}{\gamma}\right).$$

$$(\beta)\quad o = \tan^3\phi + \frac{\sqrt{y^2 - h^2}\cot\theta + A - 2y^2\mu - \frac{2ky}{\gamma}}{y^2 + \sqrt{y^2 - h^2}\cot\theta\,\mu + A\,\mu}\tan^2\phi -$$
$$\frac{y^2\mu + \frac{2ky}{\gamma}}{y^2 + y\sqrt{y^2 - h^2}\cot\theta\,\mu + A\,\mu}.$$

When from these equations the value of $(\theta)$ has been determ
ing to the small portion C D of the curve, the val
ing to the value of $(\theta)$ so determ

ie curve; in this way the curve of equilibrium can be constructed
) any required depth.

In solving the equations ($\alpha$) and ($\beta$) it will be found that, in onsequence of the cohesion of the ground, the upper parts of the lope will stand with a vertical face, or even overhanging. As it vould be out of the question in practice to have any portion of a lope overhanging, it is immaterial to examine the precise nature of the curve of equilibrium in those parts. It will be sufficient to assume that the upper part of the slope is vertical; and the first point to determine is the exact height of vertical face which the ground will maintain without slipping.

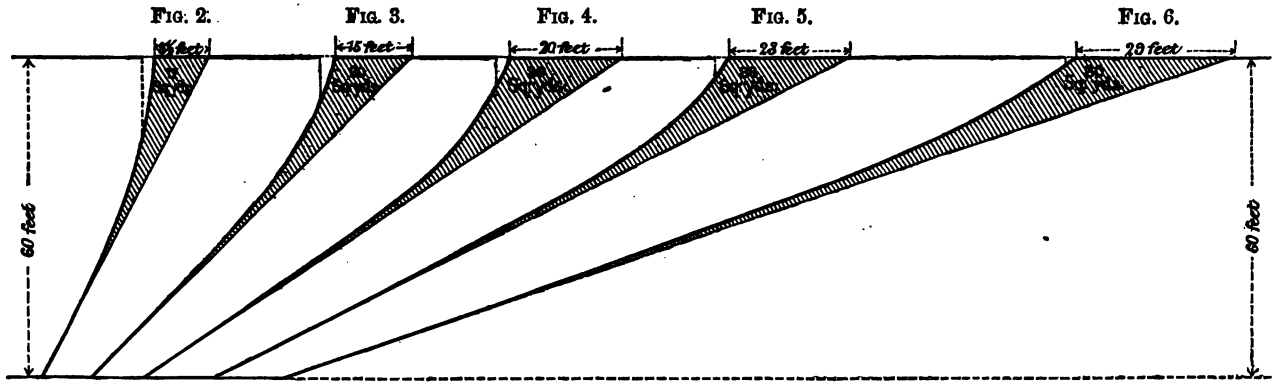
In the two equations ($\alpha$) and ($\beta$), since $\theta = 90°$, put $\cot\theta = o$, $A = o$, and $h = o$. Then dividing out by ($y^2$) the equations become

$$o = \cos\phi + \mu \sin\phi - \frac{1}{\sin\phi}\left(\mu + \frac{2k}{\gamma y}\right).$$

$$o = \tan^3\phi - \left(2\mu + \frac{2k}{\gamma y}\right)\tan^2\phi - \left(\mu + \frac{2k}{\gamma y}\right).$$

And from these equations the values of ($\phi$) and ($y$), which satisfy them, can be determined by trial, and the value of ($y$) so determined will be the exact height of the vertical face which the ground will maintain without slipping. This will define a starting point on the curve; below this point the curve must be computed step by step from the pair of equations ($\alpha$) and ($\beta$).

In order to compute and draw the curve of equilibrium corresponding to any given kind of ground, it is necessary to be furnished with the values of the co-efficients of weight ($\gamma$ lbs. per cubic foot), cohesion ($k$ lbs. per square foot), and friction ($\mu$) applicable to that ground. These must be determined from direct experiment. From experiments made by the Author, the values of the co-efficients belonging to strong brick loam were found to be: $\gamma = 125$ lbs; $k = 168$ lbs.; $\mu = 1{\cdot}150$. With these constants the curve (Fig. 2) was computed. The height of vertical face which the ground would maintain without slipping was 14·4 feet; and the curve, starting from the point so determined at an angle of about 80° to the horizontal, finally attained an angle of about 64° to the horizontal at a depth of 60 feet, corresponding to an inclination at that depth of about $\frac{1}{2}$ to 1. In this figure, and in subsequent figures, the upper portion of the curve is not shown absolutely vertical, but is drawn in with a




Curves of Equilibrium. Scale 36 feet to 1 inch.

| — | Fig. 2. | Fig. 3. | Fig. 4. | Fig. 5. | Fig. 6. |
|---|---|---|---|---|---|
| Slope at bottom. . . . | ½ to 1. | 1 to 1. | 1½ to 1. | 2 to 1. | 3 to 1. |
| Weight, per cubic foot . . | 125 lbs. | 125½ lbs. | 126 lbs. | 128 lbs. | 130 lbs. |
| Cohesion, per square foot . | 168 „ | 147 „ | 126 „ | 84 „ | 42 „ |
| Co-efficient of friction . . | 1·15 | 0·57 | 0·37 | 0·30 | 0·23 |

curve running uniformly with the curve of the lower parts of the slope, the vertical face itself being shown by a dotted line. It will be noticed that this curve is much steeper than the slope which experience has shown to be necessary for railway cuttings in strong brick loam. In fact, such ground would probably require a slope of $1\frac{1}{2}$ to 1 for safety. But it is without doubt approximately the curve of equilibrium of a clay slope in unshaken ground, having such constants of weight, cohesion and friction as those used in the investigation. It is a matter of common experience that clay cliffs in quiet places, such as brick pits, maintain permanently a remarkably steep face, often overhanging considerably at the top, for a great depth. At the same time it is the minimum curve of equilibrium, *i.e.*, the curve of equilibrium without any margin or allowance for safety; and it is the minimum curve of equilibrium only for ground which is unshaken, and in precisely the same state throughout its entire mass as the experimental specimens from which the constants were deduced. Even for ground which is unshaken a large margin of safety, in the form of a flatter curve for the slope, must be provided to meet the alteration of the constants due to irregularities of structure and crevices in the ground, the infiltration of water in wet seasons, and the dislocating effect of heat in summer and of frost and thaw in winter. In railway cuttings the ground has the additional trial of being constantly subjected to severe vibration from the passage of trains; and it is certain that this vibration is a powerful agent in causing ground to slip.

For these reasons it is clear that for railway cuttings a large margin of safety must be provided by a flatter curve for the slope. The curve of equilibrium will have the same general character as the curve already found; but it must be investigated with altered values of the constants, so as to give at the bottom of the slope such an inclination as experience has decided to be necessary for cuttings in such ground. The alteration of the constants must be considerable, but it is impossible to determine exactly how each constant should be altered. Nevertheless, it is not difficult to find by trial combinations of the constants which will produce any required slope; and the nature and circumstances of ground are of such great variety that a general discussion of the problem alone is practicable. The co-efficient of friction will be much affected by vibration, and by the infiltration of water; cohesion will be diminished by the infiltration of water, and by weak veins or crevices in the ground; the weight of the ground will be increased slightly by the infiltration of water.

Bearing in mind the circumstances which would affect the several constants, the Author has computed curves for a 60-feet cutting having inclinations at the bottom of 1 to 1, 1½ to 1, 2 to 1, and 3 to 1 respectively (Figs. 3, 4, 5, and 6). These may be taken to represent approximately the curves of equilibrium for clays of different kinds, ranging from strong compact clay to weak rotten clay, the ground in each case being supposed uniform throughout. The constants from which the curves were computed are given in the Table below the Figs., and the saving of land and earthwork by dressing the slopes to the curve of equilibrium instead of to a straight batter are marked on each diagram.

From an examination of the diagrams, and a careful consideration of the conditions from which they were computed, the following remarks are suggested:

(1) The curves embrace practically all depths of cutting. For the curves are computed from the top downwards, and at whatever depth they may be considered they are complete to that depth. Also below 50 feet or thereabouts the curves practically continue in a straight line.

(2) The inclination of the curves is very different at different depths. Consequently it is incorrect to dress the whole of a cutting to the same slope; for it is obvious that the shallow portions of a cutting will stand at a much steeper slope than the deeper portions of the same cutting.

(3) A saving of land will be effected by dressing slopes to the curve of equilibrium. The width of land saved varies from 9½ feet to 29 feet for a cutting 60 feet deep, according to the nature of the ground. This saving is almost all due to the shaping of the upper parts of the slope, and about two-thirds of it is due to the upper 30 feet of the slope. Thus it is as important to attend to the proper shaping of shallow cuttings as of deep ones. There is also an important saving in the earthwork.

(4) For the setting out of the curves of equilibrium no easy numerical rules can be given, as the curve has no simple properties. The readiest method would be to keep copies of the diagrams, and to take directly from them such guiding measures as might be needed.

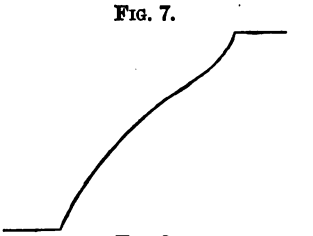
(5) When the cuttings are in clean sand, or sand much charged with water, or in the worst kinds of clay, cohesion is insignificant, and the curve of equilibrium approximates closely to a straight line. But a slope in uniform ground should never be left rounded.

### Irregular Ground.

Throughout the preceding investigation, the ground has been supposed uniform throughout; but it often varies extremely at different depths. It is frequently weak at the top, and increases in strength with the depth, till at the bottom it has nearly the strength of rock. Sometimes the ground is strong at the top and weak at the bottom, and sometimes a bed of rock is interposed between soft beds of clay or sand. In fact, every conceivable alternation of beds may be met with, and it is impossible to do more than point out the general character of the curves for the above-mentioned cases.

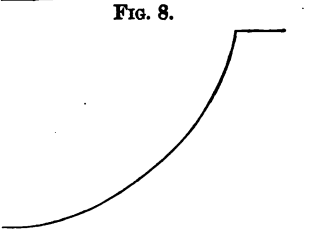
(1) If the ground be weak at the top, and increase gradually in strength towards the bottom, the curve of equilibrium will be as in Fig. 7. Here the curve at the top will be that due to the weak ground at the top, and will pass by a reversed curve towards the bottom, more or less rapidly, according as the strength of the ground changes quickly or slowly.

Fig. 7.



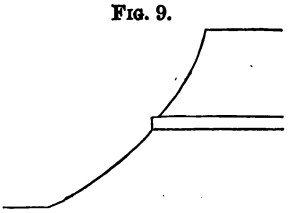
(2) If the ground be strong at the top, and grow weaker with the depth, the curve will be generally similar to that due to uniform ground, but the change of inclination will be more rapid towards the middle of the slope, and the curve will be much flatter at the bottom (Fig. 8).

Fig. 8.



(3) If a band of rock be interposed between two soft beds, the curve of equilibrium will evidently be similar to Fig. 9.

Fig. 9.



In all these cases, or in any other cases that may occur, there is no difficulty in calculating the curves of equilibrium, step by step, in precisely the same manner as was done for the curves in uniform ground, provided that the constants of cohesion and friction be known for the different parts.

### Remarks on the Maintenance of Slopes.

It will be evident, from a consideration of the high value which the cohesion of ground commonly possesses, say 150 lbs. per square

foot on an average, that it is of the greatest importance to get out cuttings in such a manner as to prevent undue straining of the ground, since the slightest dislocation deprives the ground absolutely of the support due to cohesion. On this account it is advisable to finish off the tops of cuttings completely before carrying out the cutting to its full depth, and not to leave the sides burdened with irregularities which throw an improper strain upon the ground, and frequently produce bad slips in ground which would have stood perfectly well at the intended slope if got out carefully. Another advantage in getting out the top of a cutting completely before digging deep into the hill is that it serves as an experiment on the nature of the ground, and shows whether the ground will stand at the proposed slope, without risking a bad slip. This is particularly necessary in cuttings on steep sidelong ground. The experience of most engineers shows that some of the worst slips occur in dealing with such ground, when it frequently happens that a cutting 20 feet deep will cause a slip extending 100 yards or more up the hill. In such cases the ground was evidently originally standing at its steepest slope of stability, or nearly so; consequently, if the ground is broken into, it will be necessary to restore, by means of a retaining wall, the strength of which it has been deprived by the cutting. In laying out a line of railway, it is of the greatest importance to avoid, if possible, any interference with steep sidelong ground, when it consists of clay or weak beds.

After a cutting has been completely got out, there yet remain the precautions necessary for the permanent security of the slopes. The best and most effectual security against slips extending over the whole depth of the slope is to retain the toe by a low concrete wall, well let into the solid ground; and it would probably be a judicious measure to retain all clay slopes on principle in such a manner, whether they have shown signs of slipping or not. This is the more necessary because the toe of a slope is in general its weakest part. The drainage from the slopes is, as a rule, most abundant at the toe, and the toe is also commonly weakened by a drain to carry off the water. Against slips extending over portions of a slope, the remedy which is usually most relied upon is extensive draining by deep cuts and pipe drains. There is commonly a good deal of water in slopes, and no doubt by thoroughly draining the slopes the ground is rendered drier and less likely to slip. But in order to get in the drains it is necessary to cut deeply into the slopes, and to injure the continuity of the ground seriously, and thus to deprive it of an

important source of strength. Moreover, the cuts and drains are likely to introduce more water into the slopes than would have got there naturally; and if a drain gets choked the consequences are most mischievous. The work, too, is expensive, and it may be questioned whether it would not be in general cheaper and safer to use deep drains very sparingly, and to rely more upon protecting the wet spots by hand-packed stone or concrete. Hence, for the permanent security of a clay cutting at the least expense of land and labour, it is recommended: (1) That the slopes should be carefully got out to curve with due regard to the nature of the ground; (2) That the toe of the slope should be retained by a low concrete wall, whether it has slipped or not; (3) that the wet spots and weak places on the face of the slopes should be supported by hand-packed stone.

In conclusion, the Author trusts that an attempt to bring an important and difficult subject within the range of calculation may be acceptable to the Members.

No. 1,554.—"The Chalk Water Supply of Yorkshire." By JOHN ROBERT MORTIMER.

As the character of the water supply of a district depends mainly on its geological structure, it is essential to give a short stratigraphical description of the area under investigation.

On the map (Plate 9) are shown the drift clays and superficial deposits of Holderness. These deposits cover the Chalk in a wedge-shaped mass, the thin edge of which fringes everywhere the inner margin of the gradually outcropping chalk Wolds, at elevations varying from 60 to 100 feet above sea-level. They are also found in small patches in numerous places on the summit of the Wolds. Their thick sides adjoin the sea and the Humber, and have a depth of from 50 to 200 feet, the upper portion of which, between Bridlington and Spurn, forms the cliffs, whilst the lower beds extend under the ocean.

Immediately underlying the quaternary deposits is the Chalk, which, in the neighbourhood of Hornsea, is 100 to 130 feet below sea-level. From here the Chalk rises northwards and westwards, and comes to the surface in a zigzag line. This mass is wedge-shaped, and lies with its thick side to the east. At Hornsea it is 800 feet in thickness, and at its northern and western terminations 300 to 500 feet.

Under the Chalk lie the impermeable Kimmeridge and Neocomian clays at Hornsea about 910 feet below the level of the sea. They also rise northwards and westwards, and at their outcrop, along the base of the outer margin of the Chalk, rise to an elevation of from 100 to 600 feet above sea-level. The upper side of these impervious clays forms a basin, in which in the main rest the Chalk and the drift clays of Holderness. Their thickness, though unknown, is considerable. At Malton the Kimmeridge clay was bored to a depth of 460 feet, and at Norton Vill to nearly the same depth, without passing through it.

The map, and the two sections of the water-line on the 22nd January, 1877, show that the Chalk of Yorkshire is a most important water-bearing rock, and that the enormous mass of free water is supplied entirely by the rain which falls upon its outcrop. All surface and subterranean streams from other districts are completely cut off, on the one side by the sea, and on the other side by the raised outcrop of the Kimmeridge and Neocomian

clays, and the accumulations of drift at the foot of the chalk escarpment. Moreover, the rain which falls upon the clays of Holderness is also cut off from the chalk below, and is chiefly conveyed to the Humber by surface streams and drains.

The outcrop of the Chalk, or area of absorption, is about 420 square miles, a little more than half the extent of the whole of the water-bearing area included between the sea and the outer limits or termination of the Chalk. The rain which falls upon this outcrop, known as the Chalk Wolds, less that portion intercepted by animals, cisterns, ponds, and plants, and taken up by evaporation, is absorbed by the porous surface soil, and descends through the rock until arrested by the unstable water-line in the Chalk. This water-line is not a horizontal plane, but rises northwards and westwards, and somewhat resembles the contour of the chalk in which it is contained.

The cause of the surface irregularities of this subterranean water is not of easy solution. It may be due, as suggested by Professor Prestwich, to friction, from rain-water having to percolate through a greater thickness of rock in some places than in others before reaching the water-line. Or it may be due to capillary attraction, and to the unequal upward attraction of the masses of superincumbent rock. Or it may even result from an unequal upward resistance produced by a variable diminution of the downward pressure of the atmosphere, due to loss of weight from friction in its passage through different thicknesses of rock before reaching the water-line, so that where the pressure is less the water will stand higher. It is not improbable that several forces operate at the same time to produce this apparent anomalous condition of the subterranean waters. The water beneath Holderness is held down by the superincumbent clay, and, except at times just along the outer edge of this clay, it always remains at the same height. But whenever the clay is pierced by boring, the water rushes upwards within a few feet of the surface. Leaving the edge of the clay, and proceeding either northward or westward, the unstrained water-line begins, as previously mentioned, to rise into an incline, following somewhat the contour of the hills above. The incline in some places is greatest when the water-line stands highest in the rock. As this line gradually falls, from long absence of rain, its general inclination becomes less and less marked. In the Mid-Wolds it is liable to great variation. In November and December 1874, the water in Langtoft well sank 30 feet below the surface of the ground, and the well had to be deepened several feet before the water-line was reached; while

on the 9th of January, 1877, the water in the same well reached within 27 feet of the surface;[1] thus showing between the two dates a variation of 103 feet in the height of the water-line. But on the above dates, at the edge of the clay at Driffield, 6 miles to the south of Langtoft, none of the service pumps failed to raise the water.

The extent of this subaërial water-containing chalk, measured from its outer margin to a line along the coast, is about 780 square miles. The average depth may be taken at 350 feet, giving about 282,687,000 cubic yards of water-bearing chalk.

The average annual rainfall on the Chalk Wolds is about 27½ inches, of which, the Author believes, three-fourths are added to the subterranean water, whilst not more than one-fourth is intercepted by plants, &c., and evaporation. In 1872 the rainfall at Little Driffield was 40·19 inches, causing in the autumn of that year and the beginning of 1873 a copious flow of the three Wold gypsey races (such as are called in the south of England "bournes"); and producing a maximum water-line nearly equal to the elevation in the second week of January in the year 1877. In 1873 and 1874 the fall of rain at Little Driffield was only 21·46 inches and 23·19 inches respectively. These two small annual rainfalls happening together led to great loss and inconvenience to the inhabitants in the Wold districts during the summer and autumn of 1874, by the drying up of numerous springs and of nearly all ponds and surface water; and the lowering of the water-line, so as to leave quite dry the bottoms of many wells on the Wolds. A great number of wells in this district were then deepened. The rainfall of 1876 at Malton, a slight distance from the northern edge of the Wolds, and at an elevation not much above that of Little Driffield, was 29·74 inches. At Langtoft, close to the northern edge of the wolds, and about 150 feet above sea-level, it was 32·065 inches. This, following the rather large rainfall of 1875, again produced for some time a copious flow of all the gypsey races, and an elevation of the water-line surpassing somewhat that of the autumn of 1872. Every excessive rainfall of several months' duration is followed by a maximum rise in the water-line, and the flooding of the gypsey valleys. Such occurrences are remembered by the old inhabitants of the neighbourhood as happening at irregular periods as far back as 1808, when the unusually

[1] At the above date the water-line in Cowlam well, at an elevation of about 430 feet above sea-level, and about 2½ miles W.S.W. of Langtoft, stood at 270 feet above Ordnance datum, being 108 feet above that of Langtoft well.

h flow of the gypseys was by the then vicar of Rudstone sidered sufficiently interesting to be recorded in the church ks.

Having pointed out that the Chalk Water Supply of Yorkshire ıeld as if by a sponge in the interstices and pores of a mass chalk, more than twice the extent of the denuded area which ne receives the descending rain, the Author may be allowed to te his opinion that the great change of level in the water-line, er an increase or diminution of the rainfall, is mainly due to e two following causes: First, to the chalk situated immediately ove the water-line having its pores always charged to saturation, that it cannot hold more water when immersed in it, the inter- ices of the rock being the only spaces left for the descending rain ı approaching the water-line; and, secondly, to the mass of rock aversed by the rise or fall of the water-line being in the shape of wedge, and to the area of elevation being limited to the outer lge of the reservoir or zone of outcrop. Hence the rapid and emingly disproportionate rise of the water-line after prolonged in.

When the water-line in the Mid Wolds moves upwards or down- ards to the extent of 100 feet, its rise or fall at Driffield, just ithin the feather-edge of the Holderness clays, is not more than om 10 to 15 feet. A short way within this edge no change of level kes place, the water-line being held always in the same position y the pressure of the superincumbent clay.

The discharge along the south-eastern edge of this basin, though ıry ing in degree, never ceases; while after frequent and heavy ınfalls it changes greatly. At such times the outflow finds s way underground with considerable force into the sea and ıe Humber. In certain places it produces bubblings in the ater along the shore, which have been frequently observed ear Bridlington harbour, and elsewhere along the east coast, otably in the bed of the Humber at a point between Hull and lessle. At the latter place the bubblings are known by the ame of the Hessle Whelps. Besides the subterranean outflow ıto the ocean and the Humber, there is an overflow on the mid- asin drainage, which also finds its way to the Humber and then ıto the ocean. It consists of a line of springs running over and ising through breaks in the thin edge of the clay which covers ıe inner margin of the outcropping chalk. The increase or ecrease in the discharge from this line of overflow is entirely due ) the elevation or depression of the water-line in the chalk eneath, consequent on an excess or diminution in the rainfall.

During the dry summer and autumn of 1874 the greater part of these mid-basin springs ceased to flow. But with a few such exceptional occurrences their overflow is considerable; and during wet seasons most copious. At these times the water-line rises sufficiently to produce a full flow of the three Wold gypsey races, and to form a chain of small lakes in the depressions of the surface along their course to the ocean.

Considerable as are these surface and subterranean discharges into the sea and the Humber, they are, in the opinion of the Author, equalled by the vast body of water issuing in an opposite direction. Along the base of the outer margin of the Chalk, towards the north and west, numerous permanent and intermittent springs issue, of every size from a tiny driblet to a stream sufficiently powerful to turn a mill, and several flour-mills are built near the sources of the chief of the permanent streams.

From the village of Warter northwards to Settrington the springs are most abundant, notwithstanding that these points of greatest discharge are along the most elevated portion of the edge of the basin, at the height of 400 feet to 500 feet above sea-level. This is partially due to the fact that the clays on which the Chalk rests are from 50 feet to 100 feet higher than at the escarpment,[1] at distances varying from 1 mile to 2 miles from the edge of that escarpment, thus forming an anticlinal or ridge as shown by section No. 2, from which a large volume of water flows towards the escarpment. Southwards from Warter to the Humber, and north-eastwards from Settrington to the sea, the springs become weaker and less numerous; and, on approaching the sea in one direction and the Humber in the other, they gradually flow at less elevations. This may be due in part to an increased facility afforded for the water to drain in these directions, and thus relieve the flow at the escarpment. Also, the springs on that portion of the escarpment situated between Settrington and Hunmanby must be weakened, by the water intercepted and drawn off by the great Mid Wold gypsey race. Besides the visible discharge along the outer margin of the Chalk, water must escape beneath the surface through and along beds of drift, sand, and gravel, which exist in the vale of Pickering, in places at the base of the Chalk. This underground outflow, like that on the surface, chiefly makes its way to the river Derwent.

---

[1] At the upper part of a narrow dale near the apex of the anticlinal of the clay shown in the western edge of section No. 2, the clay is visible on the surface at a point crossed by the 600-feet contour line.

Wherever there is any considerable obstruction to the escape of water along the outer margin of the chalk Wolds, extensive land-slips are caused by the great pressure of the penned-up water. Traces of these slips are numerous. The Author witnessed one near the fish-ponds at Birdsall about thirty years ago. A slip of ground, nearly 300 yards in length along the chalk escarpment, sank bodily, pushing the ground below into fissures and flexures, and leaving a vertical wall of rock from which it had parted, varying from 20 feet to 35 feet in height. This subsidence was gradual, and extended over a period of several weeks.

Great and frequent as are the changes in the height of the water-line along the zone of out-cropping chalk, and the consequent variation of the outflow from the springs, the Author believes that no amount of pumping or prolonged absence of rain would entirely stop the flow of a few of the main springs, or cause the water in the Chalk to sink far below the sea-level. For as, after excessive rain-falls, the mass of water in the Chalk becomes of sufficient weight to force its way into the ocean, it is manifest that should the water-line in the Chalk sink below a certain point through prolonged drought or excessive pumping, and thus diminish the pressure seawards to a minimum, the flow would be reversed and the water of the ocean would then prevail, and would force its way into the Chalk, and thus prevent the subterranean water-line from falling below that of the sea. Mr. J. Oldham, Cottingham, writes to the Author, that "the first well he had to do with was one made for Mr. Hawkins about fifty-six years ago, at or about the site of the entrance to the Albert Dock at Hull. The Chalk was reached at 110 feet below the surface of the land, and was penetrated 22 feet, giving a total of 132 feet, when a good supply of drinkable water was found. And for some two or three weeks prior to connecting the pump to the pipe inserted, the fact was observed that the surface level of the water in the tube was always on the same level with the water of the Humber, whether high or low tide. In bores made at Hessle, Anlaby, and Springhead, the same phenomenon as to the rising and falling of the water in the tubes takes place. And in 1846, Messrs. Easton and Amos, of London, put down a pipe at Sunk Island for the Commissioners of Woods and Forests, to the depth of 330 feet, but failed in obtaining pure water free from salt. They reached the Chalk at about 110 feet, and bored 220 feet into it." Mr. Oldham adds, that "from the waterworks at Springhead the borough of Hull is supplied with upwards of 5 millions of gallons daily."

And Mr. Villiers, of Beverly, writes on the 19th of April, 1877,

"we went through the chalk in Hull at 615 feet. We always find under the Chalk one kind of stiff blue clay very dry. In Hull and all over Sunk Island the water from the Chalk, if from deep bores, is salt, but in the interior of Holderness the water contains very little salt. There is a little salt found at Hornsea, but it soon pumps off. At Hull and at Sunk Island it is no better for pumping. The freshest water I ever found in Hull is from a bore 95 feet deep, and there is another bore 20 yards from it 300 feet deep, which contains 20 per cent. more salt. Both bores are in the chalk rock, as the Chalk in that neighbourhood is found at about 55 feet to 60 feet from the surface. The best quality and the largest quantity of water is found on the top of the chalk rock in Hull. There is a bore at the Subscription mill on the Holderness road about 95 feet deep, from which the water is better both in quality and quantity than that obtained from the adjoining deep bores."

It thus seems clear that the flow of the pure fresh water towards the sea is in the main on the surface of the subterranean reservoir along the rubbly and open rock, which is everywhere the character of the upper beds of the Chalk; and that the brackish water found at greater depths is probably due to the pressure of the ocean forcing salt water into the rock at a lower level.

The Author hopes the few facts cursorily brought together in this Paper may be convincing as to the vastness of the Chalk Water Supply of Yorkshire; and will show that, providing the wells pierce the minimum water-line, which in no place exceeds a maximum depth of 300 feet, an abundant supply of water is always obtainable. Except in proximity to the sea and to the Humber, and where it is not polluted by human habitation, it is agreeable to the taste, and free from objectionable impurities.

The communication is accompanied by a map and sections, from which Plate 9 has been compiled.

No. 1600.—"Coal-Washing Apparatus at Bessèges, France."[1] By J. B. MARSAUT. (Translated and abstracted by ALFRED BACHE, B.A., Assoc. Inst. C.E.)

ALL coal-washing apparatus depends for its action upon the difference between the density of the coal itself and that of the foreign substances it contains; and the washing operation is effected either by the fall of the stuff through still water, or by an upward current of water carrying the stuff with it. M. Marsaut, who is Engineer-in-chief of the Bessèges Coal Company (in the department of Gard, in the south of France), confines his observations to the washing of the small coal passing through square or round holes of 1½ inch (40 millimètres) side or diameter, as all stuff too large to pass through riddles of this mesh can ordinarily be cleaned more advantageously by hand-picking.

It has been shown by Herr Rittinger,[2] from theoretical investigations verified by practical experiments, that when bits or grains of any substance, of different sizes and different densities, are allowed to fall through still water, they very speedily acquire a limiting velocity of descent, which thenceforth continues uniform for each separate piece respectively; and that for irregular-shaped bits of coal, with its associated impurities, this limiting velocity in mètres per second is practically given by the empirical expression $2{\cdot}44\sqrt{D\,(d-1)}$, where $d$ is the density of the substance, and $D$ the diameter in mètres of the holes through which the stuff has been riddled. (Or $1{\cdot}28\sqrt{D\,(d-1)}$ will give the velocity in feet per second, if $D$ be taken in inches.) The classification effected by any coal-washing process, being thus influenced jointly by the sizes of the bits and by their several densities, may be appropriately designated a "sorting by equivalence," to distinguish it from the "sizing" or classification according to size alone by ordinary riddling.

In the ordinary mode of dealing with the small coal at collieries, by riddling before washing, the practical question arises, within what limits of size the preliminary riddling should be performed:

[1] The original article bears the following title, "Etude sur le Lavage de la Houille," and appeared in the Bulletin de la Société de l'Industrie minérale, 1878.

[2] "Lehrbuch der Aufbereitungskunde." Ernst und Korn, Berlin, 1867.

inasmuch as smaller bits of the foreign substances to be separated from the coal will, on account of their greater density, fall faster through the water than larger bits of the coal itself. The determination of this point depends upon the density and consequent degree of impurity which is assumed as limiting the commercial value of the washed product. Taking the density of pure coal and of the foreign matters associated with it in the seam to be approximately as given in the following table, the limiting velocities here deduced from the foregoing expression afford a means of deciding how to arrange the riddling :—

"SORTING by EQUIVALENCE" of COAL, SHALE, &c., by the LIMITING VELOCITY of FALL through STILL WATER.

| Material, in bits of Irregular shapes. | Density.* | | Limiting Velocity of Fall, in mètres per second. | | | |
|---|---|---|---|---|---|---|
| | $d$. | $(d-1)$. | | | | |
| Coal, pure . . . | 1·3 | 0·3 | 0·267 | 0·231 | 0·189 | 0·134 |
| „ shaly . . . | 1·6 | 0·6 | 0·378 | 0·327 | 0·267 | 0·189 |
| „ more shaly . . | 1·9 | 0·9 | 0·463 | 0·400 | 0·327 | 0·231 |
| Shale, pure . . . | 2·2 | 1·2 | 0·535 | 0·463 | 0·378 | 0·267 |
| „ with pyrites . | 3·4 | 2·4 | 0·756 | 0·654 | 0·535 | 0·378 |
| Pyrites . . . . | 5·0 | 4·0 | 0·976 | 0·844 | 0·691 | 0·488 |
| Diameter of holes in riddle | Millimètres | | 40 | 30 | 20 | 10 |
| | say Inches | | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{3}{4}$ | $\frac{3}{8}$ |

* The first column of Density is the absolute density $d$, taking water = 1·0; the second is the excess $(d - 1)$ above that of water.

The shaly coal of 1·6 density can scarcely be utilised as fuel; and if this therefore be assumed as the limit of density or impurity to be allowed in the washed product, it is evident that, before washing the stuff which has passed through a mesh of 40 millimètres ($1\frac{1}{2}$ inch), it should first be riddled again over a mesh of 20 millimètres ($\frac{3}{4}$ inch), to separate all below this latter size; for it is seen that the 20 millimètres shaly coal of 1·6 density falls through the water with the same velocity (0·267) as the 40 millimètres pure coal of 1·3 density; consequently the 20 millimètres shaly coal, together with all smaller stuff of greater density, would fail to be separated from the 40 millimètres pure coal by the washing. Similarly the stuff from a 30-millimètre mesh should be riddled again over a 15-millimètre mesh, to take out all that will pass through the latter; and thus for cleaning any class of raw

coal that has already passed through one riddle, it should first be riddled again over a sieve of half the previous mesh.

The sorting by equivalence, which is effected by the fall of the stuff through still water, would theoretically be performed with equal efficiency by a continuous ascending current of water, passing upwards through a layer of the stuff spread upon a sieve, if the velocity of the stream were made sufficient to carry along with it all bits coming within the assigned limit of density or impurity. Instead however of a continuous upward current, the more usual plan adopted in coal-washing machines has been to employ an intermittent or pulsating movement of the water upwards through the layer of stuff, the motion being produced by the action of a quick short-stroke single-acting piston, as in the ordinary jiggers or water-pulsatile machines. The consequence of this intermittent nature of the upward current is, that in the intervals between the pulsations a more or less forcible downward or return current occurs, filtering through the stuff on the sieve with an action that may be described as "suction," whereby the smaller particles of shale and shaly coal are drawn downwards through the interstices between the larger bits to a much lower level than they would reach without the aid of this suction; they thus pass sooner than they otherwise would through the sieve, and become deposited as "slimes" at the bottom of the hutch or water chamber beneath the sieve. Suction does not come into play in the upward pulsations of the water, because in ordinary working the charge of stuff upon the sieve is lifted bodily the instant the ascending current begins. It is in the case of poor slack, that is, coal containing dust of poor quality, that the suction is most useful; little advantage arises from it in the treatment of stuff from which the dust has previously been separated; while with rich slack it becomes even prejudicial, by increasing the proportion of pure coal carried off in the slimes. It has the important practical advantage of enabling small coal of poor quality to be washed successfully, without having previously undergone so thorough a riddling as would otherwise be necessary; and therein lies the secret, M. Marsaut considers, of the generally admitted superiority in the efficiency of the ordinary piston jiggers as compared with other coal-washing machines, which has hitherto been thought to result from some peculiar knack in working the jiggers by hand.

Passing over as out of date the old plan of washing by a stream of water, employed in the same manner as in the conical vessels used for emery sorting, or on the inclined "dead frames" used for

ore-dressing,[1] the numerous coal-washing contrivances may be grouped in three classes. (1) The first comprises all those in which the water absolutely filters through the stuff to be cleaned; as in the case of the old piston jigger, in all varieties of which, whether worked by hand or by machinery, the filtering action comes into play, as also in M. Evrard's large circular washer. Such machines are specially suitable for slack of poor quality, as they offer the important practical advantage of simplifying the preliminary riddling and dispensing with any special treatment of the slimes. The accessory action of suction is here brought to bear to the fullest extent upon the slimes, particularly where a double-acting piston is employed, lifted by mechanism in the upstroke instead of being left to rise of its own accord with the return motion of the water; the highest result in purification of the washed coal can thereby be attained, although for that very reason a serious loss of combustible material is occasioned in applying these machines to the washing of rich slack, or of small riddled stuff from which the dust has been removed, such as peas, nuts, and other sizes of small coal. (2) The second class of washing apparatus is of an intermediate character, with only partial filtration of the water through the stuff on the sieve, as in the washers of Bérard,[2] Revollier, Forey, Rivière,[3] and others, which have been designed for the purpose of dealing with large quantities of stuff in machines kept continuously at work, and of treating such small-sized stuff as impedes the return or downward flow of the water through the layer on the sieve. For poor slack they require the preliminary riddling to be more minutely carried out, in proportion as the downward filtering action of the water becomes more and more restricted; and they are more suitable for richer slack; but the results realised from their working are somewhat indefinite and variable. (3) The third class of washing apparatus includes all plans in which the action is simply that of sorting by equivalence: either by an ascending current of water, continuous or intermittent, as in the Meynier and Coppée washers, and in the latest apparatus of M. Evrard; or by simply letting the stuff descend through still water, in a fall broken up into a series

[1] Nevertheless similar plans of coal washing by means of boxes, or sloping spouts or troughs, are still employed in the North of England, the Barnsley, Wigan, and other districts. (*Vide* "Proceedings of the South Wales Institute of Engineers," vol. x., pp. 122-4; and "Transactions of the North of England Institute of Mining Engineers," vol. xv., p. 61.)

[2] "Proceedings of the South Wales Institute of Engineers," vol. vi., p. 232.

[3] *Ibid.*, vol. x., p. 294.

short drops, avoiding all pulsatile action of a piston, as is done in the new washing apparatus designed by M. Marsaut. Washers of this class are suitable only for rich slack, or else for stuff that has been properly sized beforehand by riddling; peas, nuts, and larger sizes are accordingly dealt with by this means better than duff or dust coal. The plan has in certain instances been carried out with advantages in increased production, and in simplicity and economy of working.

The following is an outline of what has been done in the mechanical preparation of coal at the Bessèges Colliery and the neighbouring Molières Colliery, belonging to the Bessèges Coal Company: together with a few of the practical results arrived at in confirmation of the foregoing principles.

*Preliminary Sizing by Riddling.*—The earliest riddles at Bessèges, dating from 1850, were simply inclined gratings with square mesh, giving three sizes of stuff:—egg coal, above $1\frac{3}{4}$ inch (45 millimètres), to be cleaned by hand-picking; chestnut coal, from $1\frac{3}{4}$ to $\frac{3}{4}$ inch (45 to 20 millimètres), to be cleaned by washing; and all smaller stuff passing through the $\frac{3}{4}$-inch (20-millimètres) mesh, to be washed separately. The first improvement was effected in 1863 by substituting simple "trommels" or cylindrical screens, each $6\frac{1}{2}$ feet long and $3\frac{1}{4}$ feet diameter, revolving on a horizontal shaft, and carrying a creeper or spiral of $1\frac{1}{2}$ foot pitch, fixed inside for travelling the stuff along from the feeding spout at one end. The total travel of the stuff over each screen was thus $38\frac{1}{2}$ feet, the first 16 feet being over a 1-inch mesh (25 millimètres), then 12 feet over a $\frac{3}{4}$-inch (20 millimètres), and lastly $10\frac{1}{2}$ feet over a $1\frac{1}{2}$-inch (40 millimètres); the 1-inch mesh was placed first, preceding the $\frac{3}{4}$-inch, with a view to facilitate the riddling of the stuff at its entrance into the trommel, where the quantity to be dealt with is the largest. At Bessèges these trommels were used exclusively till 1876, and are still working at Molières. When the stuff is shovelled into the feeding hopper by hand, 100 tons can easily be worked by each trommel per day of ten hours. Those at Molières have, since 1870, been supplied by tipping direct from the wagons by hydraulic power, increasing the quantity to 150 tons per day. These simple trommels are nevertheless attended with the disadvantage of giving the egg coal the longest travel, and of being rather short for the duff of wet slack.

A considerable improvement has been effected at Bessèges by the introduction in 1877 of inclined double or "twin" trommels, consisting of two concentric screens, one inside the other, with an annular space between, the outer cylinder being $4\frac{1}{2}$ feet diameter

and the inner 3¼ feet, and each only 5¾ feet long. The inner screen, of 1½ inch (38 millimètres) square mesh, carries two parallel spirals of 3 feet pitch, for dividing the stuff into two portions; and the egg coal delivered from the lower end, after a travel of only 20 feet, is received on a picking grate, on the bars of which the largest pieces of coal are picked out by hand, the rest falling through the grate to be picked subsequently. The outer screen, of ¾ inch (19 millimètres) square mesh, carries a spiral of 1½ foot pitch, giving the chestnut coal 42 feet travel. What falls through the mesh of the outer screen is received on a "save-all" or flat sloping riddle, oscillating rapidly, and is thereby separated into peas and duff. With this arrangement of double trommels, occupying little space, and delivering five sizes of stuff, 400 tons can be riddled in ten hours by one man or boy; while the speed can be reduced at pleasure for working wet slack more slowly. The shorter travel of the egg coal diminishes its breakage, and the longer travel of the chestnuts favours their more complete separation from the smaller sizes. The actual result of the successive improvements has been a reduction in the labour cost of riddling from about 1·2 penny per ton on the old inclined gratings, to 0·6 penny in the ordinary trommels supplied by shovel, or 0·4 penny with hydraulic tipping, and to less than 0·2 penny per ton in the double trommels with hydraulic tipping; the men earn one-third more wages, with much less labour. The riddling is purposely kept separate from the washing apparatus, in order that each process may be carried on entirely independent of the other, and the washing continued during the night while the riddling is at a standstill. The old works at Bessèges have now been re-arranged with this object, the result being that the labour cost for riddling, tramming from the riddles, and delivering into the washing apparatus, has been reduced from about 2·5 pence per ton with the old inclined gratings, and 1·8 penny with the ordinary trommels, to only 0·6 or 0·7 penny per ton at the present time.

Before the introduction of the double trommels in 1877, the stuff that had passed through a 1-inch mesh (25 millimètres) was found to yield generally about 23 per cent. of ash; 75 to 80 per cent. of it was too large to pass through a square mesh of $\frac{1}{10}$ inch (2½ millimètres), and the 20 to 25 per cent. which did pass through yielded about 25 per cent. of ash; while out of this latter lot 17 to 21 per cent. of the original quantity was too large for a mesh of $\frac{1}{16}$ inch (1½ millimètres), through which only the remaining 3 to 4 per cent. passed, yielding 27 per cent. of ash. After the

luction of the new trommels, successive re-riddlings of the which had passed through a square mesh of ¾ inch (19 millis) showed that it contained the following proportions of ar sizes, each of these being found to yield from 21 to 23 per of ash :—

| | | | | | | | Millimètres. | Inch. |
|---|---|---|---|---|---|---|---|---|
| per cent. passed *through*, and | 0 | per cent. *over*, | a | square | mesh | of | 19, | or 3-4 |
| „ „ „ | 52 | „ „ | | round | „ | | 15 | „ 5-8 |
| „ „ „ | 13 | „ „ | | round | „ | | 12 | „ 1-2 |
| „ „ „ | 12 | „ „ | | round | „ | | 6 | „ 1-4 |
| „ „ „ | 13 | „ „ | | square | „ | | 3 | „ 1-8 |
| „ „ „ | 7 | „ „ | | square | „ | | 1½ | „ 1-16 |
| Add the | 3 | per cent. passing through . . . . . | | | | | | |
| Total | 100 | original quantity of stuff. | | | | | | |

*l Piston Jiggers at Bessèges.*—The first coal-washing house at ges, erected[1] in 1850 by M. Chalmeton, Director of the Com-, and fitted up with a series of ordinary piston jiggers or water tile machines, continues to the present day, notwithstanding rogress of improvements, to be the best adapted to the nature of oal to be dealt with; the only modifications made have been in rd to the riddling, and the mode of distributing the stuff to the ers. The quantity of stuff washed in the jigger at each charge s a layer about 12 inches thick upon the sieve, and undergoes lly from 200 to 250 jigs, of such force as to lift it each time ) 1½ inch; the sorting action thus produced, irrespective of the t of the suction, corresponds with that which would result a free fall of 20 to 30 feet through still water. The charge of is admitted to the jigger from a hopper above, and the ed coal after washing is skimmed off with a shovel; the shale ining on the sieve is removed every fifth or sixth charge, and limes collecting in the bottom of the hutch below are cleared nce a day. The jiggers being worked by mechanical means, nan attends to two machines, and turns out from 15 to 16 tons ashed coal in ten hours; he is paid per ton according to the ntage of ash in the washed coal and in the refuse shale. The ing of these jiggers during the past year, 1877, resulted in following average percentages of ash, and corresponding parti-s are furnished for each of the ten preceding years :—

| | | | |
|---|---|---|---|
| Unwashed stuff from riddles . . . | 21·35 | per cent. | of Ash. |
| Washed Coal from jiggers . . . . | 7·75 | „ | „ |
| Refuse Shale . . . . . | 71·65 | „ | „ |
| Slimes . . . . . | 46·38 | „ | „ |

[1] Bulletin de la Société de l'Industrie minérale," 1st series, vol. iv., 1858–59.

The shale from the jiggers, after washing stuff that has been riddled through the 1-inch mesh (25 millimètres), contains about 10 to 12 per cent. of coal, and the slimes 25 to 30 per cent., as ascertained by testing in a bath of sulphate of zinc, the density of which is 1·4; taking this as the practical limit of density for coal as a utilisable fuel, all that floats on the liquid is coal to be saved, and all that sinks is refuse. The most coaly portion in the layer of shale remaining on the sieve of the jiggers, after removing the washed coal, is the uppermost third of the layer, which is therefore skimmed off and washed over again by itself in a separate jigger; it contains about 35 per cent. of ash. The re-washing recovers one-third of coal, containing 18 to 22 per cent. of ash, which is consequently as good fuel as the original unwashed stuff from the riddles, but cannot be further cleaned. The proportion borne by the coal thus recovered to the total weight of raw coal raised from Bessèges pit, which contains nearly ·12 per cent. of shale, is accordingly about $1\frac{1}{3}$ per cent.

From the slimes, which carry off so much larger a quantity of combustible matter, practical means of effecting its profitable recovery are as yet wanting. On removing the deposit of slimes from the jigger hutch, it is found to be stratified in a series of very regular layers, corresponding to the number of times the shale has been cleared off from the sieve; in each layer the bottom portion is consequently the richest, having been deposited while there was the smallest thickness of shale on the sieve; and the upper portions become less and less rich, with the gradually increasing thickness of shale at each succeeding charge. There is however no means of treating separately the most coaly portions, as is done with the shale; and to recover anything from the slimes, the entire quantity would have to be re-washed. The attempt to do this would be attended with so many practical difficulties, in treating such fine stuff containing 40 to 50 per cent. of ash, that the slimes are generally thrown away as waste. The loss of the 30 per cent of coal commonly contained in them has been reduced to only about 25 per cent. at Bessèges, by keeping a permanent layer of shale on the sieve of the jiggers, of never less than $2\frac{3}{8}$ inches (6 centimètres) thickness. The loss is also dependent on the number of jigs to which each charge of stuff is subjected; and the results are given of experiments on two sizes of riddled slack, jigged with pulsations ranging from 50 to 300, showing that the percentage of ash in the slimes undergoes very little fluctuation, while the proportion of the slimes themselves to the unwashed slack rises with the number of jigs. At Bessèges with 200 to 250 jigs per

ge, producing 12 to 15 per cent. of slimes which contain about er cent. of coal, the actual loss in the slimes is consequently 3 to 4 per cent. of the raw coal raised from the pit.

he black water discharged from the jiggers at Bessèges amounts bout half the weight of the washed coal, and carries off from 3 per cent. of the raw coal, in the state of mud, containing t 30 per cent. of ash.

he most advantageous size of mesh for the riddles supplying jiggers is a question depending upon two conflicting elements, ely, diminished loss of combustible matter in the washing, and rior cleaning of the coal. From extensive experiments, of ch the particulars are given, a $\frac{5}{8}$-inch round mesh (15 millires) has been found more advantageous at Bessèges than a ch square mesh (25 millimètres), and also preferable to any smaller mesh.

he practical conclusions arrived at, in regard to the use of the inary piston jiggers for coal washing, are that, while they are ntially suited for washing poor slack, there are special limits e observed in the preliminary riddling, and the duff or dust uld not be separated from the rest before washing; but that se machines are disadvantageous for washing rich slack, or stuff lled through too coarse a mesh, or coal from which the duff has ady been separated.

*érard Coal Washer.*[1]—Prior to the experience which has led to the going conclusions, a trial of Bérard's apparatus was made about l at the Company's two principal works at Molières and ège, in the hope of getting better results from it than from ordinary jiggers, both in quantity of coal cleaned and in degree leaning effected. Although this hope has not been realised, the it must unquestionably be accorded to M. Bérard of having, by remarkable adaptation of mechanical means, given an impetus he simplification of the labour bestowed upon the mechanical aration of coal. Three years' regular working of this machine Bessèges in 1864–66 showed a clear difference of $1\frac{1}{2}$ to 2 per t. in the proportion of ash in the washed coal, in favour of the inary jiggers treating the same stuff. The shale from the ard washer contained more coal; but the slimes less, owing to greater speed of working, which diminished the suction. On other hand, the machine being a continuous jigger, the stream ater passing off at the overflow above the sieve carried away a

[1] "Proceedings of the South Wales Institute of Engineers," vol. vi., p. 232.

further quantity of slimes containing a considerable amount of coal; but by catching these slimes in depositing vessels, 10 to 12 per cent. of the total quantity was recovered, in a state fit for mixing with the washed coal, without increasing the proportion of ash in the latter by more than about ½ per cent. The remaining 90 per cent. of the slimes from the overflow was not worth saving, though representing about 5 per cent. of the raw coal treated. By reducing the speed of working, so as to wash only 25 tons per day instead of 50, the proportion of ash in the washed coal during the third year was diminished 2 per cent., but the loss of coal in the slimes was at the same time augmented; and the machine proving thus no better in these respects than the ordinary jiggers was abandoned at the end of 1866, and it was determined to try a new plan of washer at Molières.

*Modified Bérard Coal Washer.*—An endeavour was then made to utilise the machinery of the abandoned Bérard washer, by modifying the apparatus in such a manner as to adapt it for washing the chestnut coal of ¾ to 1½ inch (20 to 40 millimètres), the pulsations of the ordinary jiggers not being strong enough for this larger size of stuff. The small round piston was replaced by a large rectangular wooden piston loaded with weights, which was raised slowly by a cam, and then let fall suddenly, producing a pulsation strong enough to lift the charge on the sieve to a considerably greater height; the speed of working was at the same time reduced to 30 or 35 jigs per minute, instead of 100 to 120. The shale was discharged by a creeper into a receptacle at one side of the hutch, whence it was lifted by a bucket-chain passing directly under the attendant's view. The water was never changed, there being no current; it filtered very rapidly down through the charge after each jig, owing to the size of stuff treated; but no air was drawn in downwards with it, notwithstanding that the piston was lifted by independent mechanical means, instead of by the return motion of the water itself. The altered apparatus thus retained none of the characteristic features of the Bérard washer, and it effected a substantial improvement in the washing of the chestnut coal at Bessèges, from 60 to 70 tons of the unwashed stuff of that size being easily treated in one machine in ten hours, with one attendant. Eight years' working, 1870–77, of which the particulars are given for each year, shows that with unwashed chestnut coal containing 26 per cent. of ash, the percentage of ash in the washed chestnuts was from 12½ to 17½, in the shale from 66 to 71, and in the slimes from 28½ to 43½ per cent. These rich slimes however amounted to 9 to 12 per cent. of the unwashed stuff, and

half of them was coal containing only 15 to 20 per cent. of ash, which was thus at least as good as the raw coal from the pit; and the importance of this loss has now decided the final abandonment of the whole apparatus.

*Coal-Washing Apparatus at Molières.*—The new coal-washing plant erected in 1867, after the abandonment of the Bérard machine at Bessèges, consisted of four washers; and two more of the same construction were added in 1876. These were designed with a view of preserving all the essential features in the working of the ordinary jiggers, and at the same time of remedying various imperfections of detail. In the improved washers, which are entirely above ground, the hutch beneath the sieve is made of large size, so that the water shall not become too heavily charged with mud by the accumulation of slimes from a whole day's working; and the slimes are emptied out of the hutch without having to remove the sieve, which remains undisturbed, and always protected from contact with the coal by a permanent layer of shale upon it. The length of the sieve is made sufficient to ensure the stuff receiving at least 200 jigs during its passage over the sieve, when 30 tons of washed coal are being produced from each machine in ten hours. The quantity of stuff supplied to the washer can be varied at pleasure by means of a special distributing apparatus, by which it is caused to fall in a shower into the water, and thus to become at once thoroughly soaked, in readiness for undergoing the desired sorting by equivalence. The shale and coal sink gradually to their respective equivalent levels in the charge on the sieve, without the coal ever going too far down and having to make its way up again. A special compartment is added for the reception of the heavier and more shaly portions of the coal, which can be removed at pleasure from the washed coal and refuse shale by the attendant, who looks after two machines, these being coupled in pairs, with a single bucket-chain delivering the washed coal from each pair. The thickness of the layer of shale upon the sieve increases but slowly, owing to the large area of the sieve; and the jigs act with less and less force upon the stuff as it traverses the length of the sieve from the point of supply to the end where the washed coal is delivered. The machine is a strictly continuous jigger, but without any current of water; and no water is lost except what is carried off in the washed stuff. Owing to the entire absence of all stoppages for charging the stuff, or for removing the washed coal and shale, the production is doubled for the same area of sieve, in comparison with the ordinary jiggers.

The stuff hitherto supplied to these washers from the coal seams worked at Molières, which are of very various qualities, has been of an extremely tender nature, containing much poor dust that does not soak readily in the ordinary jiggers. The relative proportions of smaller sizes contained in stuff which had passed through a square mesh of 1 inch (25 millimètres) was found by successive re-riddlings to be as follows, the quantity of ash ranging from 20 to 22 per cent. :—

| | | | | | | | | Millimètres. Inch. |
|---|---|---|---|---|---|---|---|---|
| 100 per cent. passed *through*, and 0 per cent. *over*, a square mesh of 25, or 1. | | | | | | | | |
| 98 | „ | „ | „ | 2 | „ | „ | „ | 19 „ 3-4 |
| 93 | „ | „ | „ | 5 | „ | „ | „ | 15 „ 5-8 |
| 86 | „ | „ | „ | 7 | „ | „ | „ | 12 „ 1-2 |
| 65 | „ | „ | „ | 21 | „ | „ | „ | 6 „ 1-4 |
| 32 | „ | „ | „ | 33 | „ | „ | „ | 3 „ 1-8 |
| 10 | „ | „ | „ | 22 | „ | „ | „ | 1½ „ 1-16 |
| | | | Add the | 10 per cent. passing through . . . . . | | | | |
| | | | Total | 100 original quantity of stuff. | | | | |

The results of the working of these washers at Molières during the seven years 1868–74 are given separately for each year; and the following are the extreme yearly averages of the percentages of ash, together with the mean of the whole period :—

| 1868–74 | Percentages of Ash. | | |
|---|---|---|---|
| | Lowest. | Highest. | Mean. |
| Unwashed stuff from riddles. . . | 21·85 | 25·06 | 23·58 |
| Washed Coal . . . . . | 9·18 | 12·48 | 11·36 |
| Shale . . . . . | 57·45 | 64·94 | 61·32 |
| Slimes . . . . . | 34·32 | 48·10 | 44·48 |

The proportion of ash in the washed coal was here not only too high to be considered satisfactory, but also too fluctuating, in consequence of the varying nature of the supplies obtained from the different seams worked. A trial was therefore made of washing the stuff from each of the nine seams separately; and the results obtained, of which the particulars are given, led to a plan of so apportioning the quantities supplied to the washing apparatus from the several seams as to ensure a practical uniformity in the quality of the washed coal, within the assigned commercial limits.

In this way the range of the yearly averages during the next three years 1875–77 was narrowed as follows:—

| 1875-77 | Percentages of Ash. | | |
|---|---|---|---|
| | Lowest. | Highest. | Mean. |
| Unwashed stuff from riddles. . . | 20·79 | 21·10 | 20·98 |
| Washed Coal . . . . . | 10·28 | 10·82 | 10·49 |
| Shale . . . . . | 64·88 | 73·78 | 69·81 |
| Slimes . . . . . | 39·17 | 41·43 | 40·03 |

In trials made by riddling the washed coal, the duff or dust passing through meshes of $\frac{1}{16}$ and $\frac{1}{12}$ inch ($1\frac{1}{2}$ and $2\frac{1}{3}$ millimètres), was found to be as thoroughly cleaned as the bulk of the washed coal itself. The general result of the arrangement of the coal-washing plant at Molières has thus been, that a marked improvement has been realised in the application of washers acting on the principle of filtration of the water through the stuff treated.

*Marsaut Coal Washer.*—In this apparatus, which has recently been erected and is now in practical work at Bessèges, the principle adopted is that of letting the charge of stuff, carried upon a movable sieve, fall through a great depth of still water, breaking up the total height of fall into a series of short drops, and doing away with all intentional disturbing action, in order to give free play to gravity. The notion of a free fall through still water is not new, having previously been advocated by M. Pernolet, Sen.;[1] but it remained to be carried out in practice, as has now been done by M. Marsaut, whose apparatus, while resembling in general arrangement that of M. Gervais,[2] differs from the latter in employing a continuous descent, either in a single fall or in successive stages, regulated with absolute control by a hydraulic piston, instead of proceeding by alternate up and down strokes produced in the ordinary way by steam power.

On M. Marsaut's plan, as carried out at Bessèges, a large rectangular kieve or tank is constructed of oak, about 6 feet long, 10 feet wide, and 24 feet deep, open at the top, and provided with sliding doors in the bottom, for discharging the slimes into a cast-iron hutch beneath, without stopping the washing. Above

[1] "Annales des Mines," vol. xx., 1851, pp. 379 and 535.

[2] "Bulletin de la Société de l'Industrie minérale," 1st series, vol. iii., 1857-8, p. 499.

the kieve is an inverted hydraulic cylinder, the piston-rod of which carries at its lower end an iron cage, about 10 feet high, sliding between guides from top to bottom of the kieve, with less than ¼ inch clearance all round. The cage bottom is an ordinary coal-washing sieve, and the ends of the cage are left entirely open; on the closed sheet-iron sides are fixed horizontal ledges, one above another, on which slide three rectangular wood frames, like drawers without bottoms, fitting loosely within the cage, the depth of each frame being determined according to the quality of the coal to be washed.

The kieve being filled with water to the top, a charge of from 3 to 5 tons is let fall from a shoot overhead into the cage, which is held up in the top of the kieve by bolts at the sides, the height of the shoot being such as to ensure all the stuff becoming thoroughly soaked at once by falling into the water in the kieve. By means of the hydraulic cylinder from which it is suspended, the loaded cage is first subjected to two or three jigs of considerable height, for equalising the distribution of the charge over its area; and it is then allowed to fall to the bottom of the kieve by a regular succession of short drops, the height of each drop being adjusted beforehand to suit the size of the stuff treated, and capable of being varied at pleasure from ¾ inch to 8 inches (2 to 20 centimètres), by regulating the escape of the water from the hydraulic cylinder. On the cage reaching the bottom of the kieve, a few seconds' pause allows the largest of the minute light particles that have not fallen so fast as the rest, to become deposited upon the charge. The cage is then drawn up out of the water, and held in position by side bolts, while the three sliding frames are successively pushed out at the front by a horizontal hydraulic cylinder behind, thereby discharging into three separate hoppers the washed coal, the stuff to be re-washed, and the shale. Level with the upper part of the kieve is an overflow tank, of about equal area and 2½ feet deep, for diminishing the variation in water level consequent upon the alternate filling and emptying of the cage. A return pipe leads from the bottom of this tank into the lower part of the kieve, and is fitted with a floating check-valve opening downwards to prevent the water from being driven upwards through it during the descent of the cage.

With a charge of from 4 to 4¼ feet thickness (1·20 to 1·30 mètre) in the cage, a total broken fall of 10 to 13 feet height (3 or 4 mètres) through the water in the kieve is generally sufficient for effecting the sorting by equivalence. Should the kieve not be deep enough, or the sorting not perfect enough, the

fall can be repeated with the same charge as many times as may be necessary. The same water is used over and over again, without renewal except of what is carried off in the stuff treated; the whole is drawn off, when desired, while the apparatus is not at work.

The action of this apparatus ensures an almost perfect sorting by equivalence. At each drop of the cage the water passes through the sieve, always in the same upward direction, at a speed due to the restricted area of passage and the relative weight of the immersed cage with its load. The mass of stuff in the cage is thereby lifted off the sieve, or rather the sieve drops away from beneath it, while the charge remains momentarily at rest; then all the separate particles of the charge fall severally through the still water with their own individual limiting velocities, modified only by their mutual interference as in all washers. When the stuff has been well sized by riddling, the sorting by equivalence must necessarily come sooner or later into operation. When the sizing has been imperfectly done, the sorting also, as in all other washers acting by an upward current without filtration, will be less thorough; but the inferiority will not be so great as in washers where the current ascends unequally through different portions of the charge, or partakes of a horizontal motion towards an overflow. All sizes of stuff, down even to dust, can be washed in this apparatus, when treated separately according to their size, inasmuch as the height of fall at each short drop is optional, and the sorting is done in still water, which has never to pass down again through the charge, so that neither the advantages nor the inconveniences of suction enter into the process. It is thus specially suited for the washing of chestnuts, nuts, peas, and other properly-sized stuff, as well as of rich slack; and also for the partial cleaning of poor duff, from which the peas and larger sizes have been riddled out.

The Marsaut washer already at work at Bessèges, and a second now in course of construction there, are intended for washing chestnuts of $\frac{3}{4}$ to $1\frac{1}{2}$ inch (20 to 40 millimètres), and nuts of $\frac{5}{8}$ to $\frac{3}{4}$ inch (15 to 20 millimètres); also for re-washing the coaly shale and the slimes from the old jiggers; and for the wholesale treatment of shaly stuff, to the extent of removing from it, without loss of combustible fuel, the greater part of the shale or stones, so as to obtain a commodity marketable for gasworks or for small smiths' forges. From practical trials at Bessèges it is found that 120 to 150 tons of washed coal can without difficulty be turned out in ten hours by one man or boy from this washer, the working of which takes only about 1 HP.

A comparison of the working of the Marsaut washer with that

of the modified Bérard washer at Bessèges, in treating chestnut coal of from ¾ to 1½ inch (19 to 38 millimètres) square mesh, has furnished the following results:

| | Bérard modified. | Marsaut washer. |
|---|---|---|
| Total quantity of stuff treated, tons | 803 | 1575 |
| Percentage of Ash { Unwashed stuff | 23 to 26 | 23 to 26 |
| Percentage of Ash { Washed Coal | 14·6 | 13·3 |
| Yield, percentage of Washed Coal | 79·0 | 84·0 |
| Waste { percentage of Shale | 11·6 | 12·5 |
| Waste { percentage of Slimes | 9·4 | 3·5 |
| | 100·0 | 100·0 |

The rich waste slimes from the modified Bérard washer, amounting as previously stated to 9 to 12 per cent. of the unwashed stuff, and containing an average of 36 per cent. of ash, are now re-washed on a large scale and very cheaply in the Marsaut washer; and yield about half coal containing only 18 per cent. of ash, thus leaving only half waste containing 53 to 55 per cent. of ash. The 3 to 4 per cent. of slimes from treating the chestnuts in the Marsaut washer contain from 28 to 30 per cent. of ash, and can also be re-washed, or even used at once for firing steam boilers, being found to make about one-third less steam than ordinary raw coal.

In comparison with the ordinary jiggers, the treatment of nuts ranging between a square mesh of ¾ inch and a round mesh of ½ inch (19 to 12 millimètres) shows a sensibly equal degree of cleaning in the Marsaut washer, the detailed particulars being given of the comparison. But the treatment of the small unsized stuff passing through the same meshes shows the cleaning by the Marsaut washer to be considerably inferior: thus practically confirming the importance, previously arrived at from theoretical considerations, of sizing the stuff beforehand by re-riddling, with meshes arranged in the proportion of half to one, when the washing is to be done by simple sorting by equivalence. While in the ordinary jiggers, acting by filtration through the stuff, the suction gives them an important advantage in the treatment of poor slack, the larger yield from the Marsaut washer shows very clearly the advantage of treating rich slack by the plan of sorting by equivalence. By re-washing in the ordinary jiggers the washed coal from the Marsaut washer, it is shown that, conformably with theory, the inferior degree of cleaning effected by the latter in the case of poor slack is due solely to the portion of slimes remaining in the washed charge of the Marsaut washer.

No. 1,599.—"On the Progress of Public Works Engineering in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By L. F. VERNON-HARCOURT, M.A., M. Inst. C.E.

THE object of this communication is to record briefly, the progress achieved in the various branches of civil engineering relating to public works abroad, as gathered from the Abstracts of Papers in Foreign Transactions and Periodicals which have been published in the Minutes of Proceedings.

The first place must be assigned to the St. Louis Bridge over the Mississippi,[1] designed by Mr. James Eads, M. Inst. C.E. This bridge, which carries a roadway above and a railway below, on girders formed of two arched steel tubes braced together, has two spans of 502 feet and a centre span of 520 feet. It supplies a proof that, by the introduction of steel instead of iron, the weight of the superstructure of a bridge may be considerably diminished, its cost reduced, and large spans adopted even for carrying two roadways. The success of the undertaking furnishes a forcible argument in favour of removing the restrictions placed hitherto upon the employment of steel in this country. The method of erecting the bridge without scaffolding is worthy of notice. The girders were built out from the piers for a quarter of their length, and being fastened to the pier at the springing bore their own weight like a bracket, and the remaining portion was added by supporting their ends by iron ties from temporary erections on the piers. The principal object of forming such large spans was to diminish the number of piers, as the foundations were difficult and costly. The foundations for the piers of this bridge have been described in a Paper by Mr. Francis Fox, M. Inst. C.E.[2] At the time of their execution, the depth of the bottom of the east pier, 102 feet below low water, was the greatest on record. Other instances of pneumatic foundations are given in the Abstracts, amongst which may be mentioned the résumé of various kinds of foundations for large bridges by Herr Funk,[3] in which reference is made to the East River bridge caisson, and to a bridge which

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. li., p. 293; [2] vol. xxxiv., p. 30; [3] vol. xlix., p. 299.

is being built over the Lymfjord in North Jutland on iron caisson foundations reaching a depth of 118 feet below low water. The recent Paper "On Foundations," by Professor Gaudard,[1] renders further reference to these and other instances unnecessary.

The Kentucky river bridge[2] is worthy of notice for the manner in which the centre truss, 275 feet above low water and 375 feet span, was erected without scaffolding. Temporary piers were erected between the abutments and piers; the girders were then built out from the rock abutments on each side, being supported by the anchorage bolts till they reached the temporary piers. The building of the girders was next continued till the permanent piers and eventually the centre of the centre span was reached, and the two portions united. The account of the Dwina bridge at Riga[3] shows how large foundations have been put in under peculiar difficulties, exposed to a rapid stream and the breaking up of ice. The Moerdijk bridge over the Hollandsche Diep,[4] whose foundations have been described in a Paper by Sir J. G. N. Alleyne, Bart., M. Inst. C.E.,[5] is chiefly remarkable for its length, as the estuary where it crosses is 2,840 yards wide. The Marseilles swing bridge[6] is an instance of a large and heavy bridge being moved round with perfect ease in three minutes by one man with the aid of hydraulic machinery.

Light railways and narrow-gauge railways have been introduced more extensively abroad than in this country, owing to the population being more scattered, to the absence of good roads, and to the importance of obtaining means of communication at the least possible cost. Also, in many mountainous districts steep gradients and sharp curves cannot be avoided in laying out railways, and the gauge and locomotives have to be made subservient to these requirements.

Amongst the railways where the standard gauge is adhered to, the light railways in Hungary[7] must be mentioned, as they represent the class of railway contemplated in the clause in the Regulation of Railways Act, 1868, authorising the construction of light railways in this country, of which there are only three actually open for traffic, though others have been authorised, and one or more in course of construction. The two light railways in Hungary are each about 29 miles long, and pass through a fertile district having bad roads. They are laid with rails

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. l., p. 112; [2] vol. lii., p. 307, also vol. liv., p. 152; [3] vol. xlv., p. 277; [4] vol. xlv., p. 279; [5] vol. xlii., p. 223; [6] vol. xlii., p. 305, and vol. xlvii., p. 222; [7] vol. xlvi., p. 282.

weighing 51 lbs. per yard, and cost little over £4,000 per mile; the greater portion of the land was given for the railway; and the country being fairly level, the earthwork was small, the gradients are slight, and the curves are few, the sharpest having a radius of 20 chains. These afford a good instance of railways made economically, at the request and with the assistance of the landowners, for the purpose of obtaining the necessary means of communication. Lines like these are, in the Author's opinion, the proper ones for supplying deficient railway accommodation in parts of England where the traffic would be unlikely to render lines constructed in the ordinary manner remunerative, and the hearty support of the landowners is an essential element in such undertakings. In Sweden this class of railway appears to have been extensively and successfully adopted, 1,730 miles being open for traffic or in course of construction.[1]

The Uetli railway[2] is a totally different type of line. It was made for the purpose of reaching the summit of the Uetli mountain, with steep inclines and sharp curves; the worst gradient is 1 in 14, and the sharpest curve 6·7 chains radius; the rails weigh 60 lbs. per yard. It rises 1,310 feet in its length of 5·7 miles, and cost £11,100 per mile. It is worked by six-wheeled coupled engines, proving that inclines of 1 in 14 can be safely ascended by locomotives. The train, composed of three carriages, performs the ascent in half an hour, and in its descent is kept under perfect control by air brakes.

The mètre gauge has been adopted for several railways: for instance, on the line of Ergastiria in Greece, of Mokta-el-Hadid in Algeria,[3] on three lines in Switzerland,[4] and in France, Sardinia, and Austria. Bessemer steel rails were adopted in some of the above instances weighing from 41 to 57 lbs. per yard; the radius of the sharpest curve is about 3 chains, and the maximum gradient 1 in 28. In India this gauge has been adopted for all the narrow-gauge lines, of which there are 2,700 miles projected, and about one-third of these were completed in 1874. From a valuable collection of statistics about narrow-gauge railways, by M. Morandière,[5] it appears that the number of these lines has increased enormously of late years; the total number of miles opened for traffic in 1874 being 5,040, and 10,812 miles being under construction. The United States head the list with 2,040 miles open, and

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlvii., p. 326; [2] vol. xl., p. 275, and vol. xlix., p. 307; [3] vol. xxxix., p. 338; [4] vol. xli., p. 273, and vol. xlvii., p. 326; [5] vol. xlvii., p. 324.

7,552 in construction. India comes next, and then Canada, Australia, New Zealand, and Russia, whilst Great Britain is near the bottom of the list with 26 miles, being less than Java, which possesses 34 miles. There are twenty varieties of gauge on these lines, lying between 1 foot 6 inches and 4 feet; but next to the mètre gauge, a gauge of 3 feet 6 inches appears the most common, having been adopted in Norway, Canada, the Cape, and on some American lines. It is natural that narrow-gauge lines have been little developed in England, France, Germany, and other continental countries, as the objections to the break of gauge in India, urged by several speakers in the discussion on Mr. Thornton's Paper on State Railways in India,[1] apply with much greater force to the principal countries of Europe. An alteration in gauge can only be expedient in cases where it would be impossible to raise sufficient capital for constructing an ordinary-gauge line, and the choice lies between a narrow-gauge line and none at all. An instance of this occurred in the Grand Duchy of Oldenburg, where, in order to connect Ocholt and Westersede,[2] each situated on railways of ordinary gauge, it was necessary, owing to the poverty of the country and the scarcity of the population, to construct the cheapest possible narrow-gauge line. This railway, which is nearly 4½ miles long, was constructed in 1876 in less than six months, at a cost, including rolling-stock, of £10,450; it was laid to a ¾-mètre gauge, with Bessemer steel rails weighing 25 lbs. per yard. Four trains run each way daily at the rate of about 13½ miles an hour; the fuel used is peat, and the daily expenses amount to only £1 9*s*. The Eibenthal mineral line[3] furnishes an instance of a narrow-gauge railway economically constructed through a hilly country. The gauge is 2 feet 6 inches; curves of 1 chain radius have been adopted, and when the line, at present worked by horses, is made available for locomotives, the total cost, including rolling stock, will amount to only £1,857 per mile.

Riggenbach's rack system for surmounting steep gradients, first adopted on the Rigi railway,[4] has been extended to seven other railways.[5] In the Ostermundingen railway[6] the central rack rail is only laid for the rising portion of the line. The locomotive works like an ordinary one along the level, and when it reaches the ascent of 1 in 10, the machinery is put in gear with the rack. A similar arrangement has been adopted on the Wasseralfingen

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxv., p. 214; [2] vol. l., p. 244; [3] vol. lii., p. 320; [4] vol. xxxvi., p. 103; [5] vol. lii., p. 318; [6] vol. xli., p. 277.

railway,[1] which has a gradient of 1 in 13, for about half a mile in length. Herr Wetli has invented a system for drawing trains up steep inclines[2] by the help of a drum, placed under the locomotive and connected with the driving wheel, with spiral threads, running in opposite directions from the centre to the sides of the drum, which wind along a pair of guide rails placed in a $\wedge$ form at short distances apart. Herr Brockmann considers this system superior to that of the Fell railway, and also to that of the Rigi railway, in which the teeth of the central rack cannot be made strong enough to bear heavy traffic. Endless wire ropes are used for drawing the tram-cars up some steep streets in San Francisco,[3] the connection between the rope and the car being so contrived that the rope is entirely below the road level, and causes no obstruction whatever to the ordinary street traffic.

Tramways along streets and public roads are being gradually extended. A concession was granted in 1873 for laying down 66 miles of tramways in Paris;[4] and a steam tramway along the high-road from Cassel to Wilhelmshöhe has been recently opened.[5] Compressed air was tried first on this latter tramway, but proving a failure, Messrs. Merryweather's steam engines were substituted, which can draw two fully loaded cars up the gradient of 1 in 16·6. In Paris, Messrs. Merryweather's locomotive, the fireless or hot-water locomotive[6] of M. Francq, and M. Mékarski's compressed-air engine,[7] have been tried. It is stated that the use of the steam locomotive in Paris has not produced a saving of expense. This is contrary to the experience gained with similar engines at Copenhagen, where a saving of 40 per cent. was effected in the cost of working; with locomotives on the light Firmy railway,[8] where a saving of one-third was made; and with Baldwin's steam car in America,[9] where 18 per cent. was saved. The employment of fifteen fireless or thermo-specific engines on the New Orleans tramway effected an economy of 50 per cent. over the traction by horses. The performance of M. Francq's engine is to be further tested on the Paris tramways. M. Mékarski reckons that traction by his engine costs the same as with steam locomotives, and effects a saving of 25 per cent., or, according to his latest calculations, 40 per cent.,[10] on the total cost of traction with horses. A tramway in the suburb of Brussels is worked by a steam locomotive,

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liii., p. 336; [2] vol. xl., p. 274; [3] vol. lii., p. 337; [4] vol. li., p. 319; [5] vol. lii., pp. 309 and 338; [6] vol. xxxix., p. 347, and vol. xlv., p. 289; [7] vol. xliii., p. 383, and vol. xliv., p. 254; [8] vol. l., p. 246; [9] vol. li., p. 317; [10] vol. liv., p. 332.

entirely encased, to avoid frightening horses. It draws a weight of 2½ tons up an incline of 1 in 50, at the rate of 7½ miles an hour.[1] Special compact locomotives, similarly disguised, have been used on tramways at Belfort and New Orleans; and locomotives have been introduced on some tramways in Italy.

A steam carriage, made entirely of steel, and weighing about 4 tons, for carrying twelve passengers, or drawing goods along an ordinary road, has been designed by M. Bollée.[2] It accomplished a journey of 150 miles in eighteen hours. It can easily travel 12 miles an hour on the level, and 5½ miles up an incline of 1 in 20, drawing a weight of 4 tons. It is easily steered through a town, and is said not to frighten horses, owing to the little noise it makes. M. Belpaire has designed a steam carriage[3] furnishing accommodation for fifty passengers. It can travel at the rate of 45 miles per hour on the level, and 25 miles per hour up an incline of 1 in 62. The working expenses are reckoned at 1*d.* per mile run.

A description of the Heberlein continuous brake is given by M. Massauge.[4] It was applied in 1874 to a train running between Brussels and Luxembourg, and acts on the principle of stopping a train by force accumulated during its motion. A new counter-pressure and vacuum brake, an improvement on the Le Chatelier system, is also described.[5] These are the only continuous brakes to which reference is made in the Abstracts, but it is natural that less attention should have been paid to this subject abroad than in England, as except on a few of the principal through routes the speed of the trains abroad is much less than in this country.

A new steam pile-driving machine, invented by Herr Lewicki,[6] was used on the river Dwina regulation works, by which, on an average, fifty piles were driven per day. From a series of experiments it was found that the steam pile engine did twenty-eight times as much work as an ordinary pile engine worked by four men; and the cost is estimated at 8¼*d.* per pile for the steam ram, and 4*s.* 6½*d.* for an ordinary ram. The peculiarity of the pile-driving apparatus described by Herr Weber[7] is that a single steam engine controls several rams. The apparatus consists of an engine, of any kind with which driving bands can be used, the power distributor, and the ropes or chains for lifting the monkey. This invention was used on the Elbe at Dresden, for driving the piles

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liii., p. 347; [2] vol. xliii., p. 382; [3] vol. liv., p. 328; [4] vol. xliv., p. 254; [5] vol. xli., p. 289; [6] vol. xl., p. 316; [7] vol. xli., p. 257.

of a quay wall, 541 yards long, where three pile drivers were used. The work of driving about two thousand one hundred piles into a bed of rough gravel and stones, to a depth of from 3½ to 7 feet, occupied thirty-two days. If ordinary hand pile drivers had been used, the cost would have been increased by about 14 per cent., and the work would have lasted at least fifty-five days.

The powder-ram, invented by Mr. Shaw in the United States, and improved by Herr Riedinger,[1] was used in constructing a bridge over the Elbe at Dresden. A cartridge of gunpowder, thrown into a mortar resting on the pile to be driven, is exploded by the fall of the ram, which drops into the mortar, and the gases formed in the explosion both drive the pile down and shoot up the ram to its original position. This ram is said to be rapid, efficient, and cheap. About twenty-seven piles could be driven per day, and the cost per pile, driven 7·2 feet, is reckoned at 8*s.* 6*d.* The great apparent difference in rapidity and cost between the results obtained with the powder-ram on the Elbe and the steam pile driver on the Dwina must be partially due to the difference in the bed of the two rivers—the bed of the Elbe consisting of rough gravel and stones; and a sort of quicksand, overlying sand mixed with clay, forming the Dwina river bed. Pile-driving in sand by the injection of water,[2] from pipes carried down the sides of the piles, has proved very expeditious and efficient at the new harbour works at Calais, doing the work in about an eighth of the time occupied by the ordinary methods.

Though some important sewerage works, such as the drainage of Berlin,[3] of Rome,[4] and of Düsseldorf,[5] are described in the Abstracts, there is no record of the introduction of any new system for dealing with sewage. The sewage of Berlin is to be disposed of by irrigation, and at Rome and Düsseldorf the sewage is discharged into the Tiber and the Rhine. At Paris considerable pollution of the Seine occurs from the influx of the sewage; the sluggish nature of the stream favours the deposit of the solid refuse matter, estimated at 130,000 tons annually, and dredging has to be resorted to for keeping open the mouths of the sewers. The Seine Pollution Commissioners[6] unanimously rejected all chemical methods of purification, and expressed their conviction, from the results of irrigation tried on the plains of Gennevilliers,[7] that irrigation was the proper method of

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliii., p. 330; [2] vol. xlv., p. 315; [3] vol. liii., p. 312; [4] vol. xl., p. 307; [5] vol. xlv., p. 317; [6] vol. xliii., p. 359; [7] vol. xxxix., p. 380, vol. liii., p. 193, and p. 326.

disposing of the Paris sewage. These sandy plains have an area of 800 acres. The effluent water after irrigation contains only 1 part or 2 parts of nitrogen, having previously contained 44 parts. The improvement of the irrigated land in productiveness is very manifest. Vegetables, fruit-trees, and flowers grow well on the land, and the gross yield per acre is from £24 to £48 in the open fields, and in some well sheltered and cultivated parts it has reached £112. At Dantzic[1] sewage irrigation experiments, commenced in 1871, have proved satisfactory both from a sanitary and an agricultural point of view.

Hydraulic engineering occupies a prominent place in the Abstracts, and many important works, such as breakwaters, harbour improvements, reclamation works, reservoir dams, the regulation of rivers, the irrigation of dry or barren plains, and waterworks for towns, are described; but most of the articles are valuable rather as records of successful applications, modifications, or extensions of well-known principles, than as embodying any special novelties of design. The dam[2] across the valley of the Gileppe is a notable instance of a masonry dam made exceptionally strong for retaining a volume of water amounting, when the reservoir above it is full, to 16,010,000 cubic yards, and covering an area of 198 acres. It is 154 feet high, 216 feet broad at the base, and 49¼ feet broad and 771 feet long at the top. The Furens masonry dam, across the valley of Enfer,[3] having a section which approximately coincides with the theoretical law as given in the article on the Gileppe dam, is 170 feet high, 110 feet broad at the base, and 9·8 feet broad at the top. These dams, however, whilst claiming notice on account of their size, are not quite without precedent, as the Alicante dam, nearly three centuries old, is 134½ feet high.

In supplying the Aix (Provence) district with water from the river Verdon, it was necessary to convey the water across the valley of St. Paul.[4] As the construction of an aqueduct would have caused considerable delay, and involved a large expenditure, the novel expedient of carrying the water across the valley in an inverted siphon was adopted. Two wrought-iron pipes, 5 feet 9 inches in diameter, form the siphons; they are laid horizontally across the bottom of the valley for a length of 322 feet, and rise on each side

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxix., p. 379, and vol. xliv., pp. 276 and 279; [2] vol. xlviii., p. 312; [3] vol. xli., p. 243; [4] vol. xlvi., p. 300, and vol. xlix., p. 346.

of the valley, with inclinations of 1 in 2·44 and 1 in 2·7, for lengths of 251 and 276 feet respectively.

The drainage of Lake Fucino,[1] rendered advisable from the absence of any natural outlet for the rain falling within its basin, is chiefly interesting for having been contemplated by Julius Cæsar, attempted by some of the Roman emperors, and again in the middle ages by Frederick II., and at length accomplished within the last ten years. The water is conveyed into the river Liris through an egg-shaped tunnel (19 feet by 13 feet) 6,887 yards long. In the construction of this tunnel twenty-eight shafts and two inclined galleries were made. The lands bordering on the lake, which were flooded in wet weather, and converted into unwholesome marshes in dry weather, have been greatly improved in value, and 35,000 acres have been reclaimed by lowering the waters of the lake.

The difficult task of keeping open a navigation channel at the mouth of the Mississippi[2] has been successfully accomplished, by contracting the South Pass into a uniform channel, 850 feet wide, by wooden jetties on eachside,[3] the channel being for a time still further confined at the sea end by wing dams to increase the scour; and mattress sills have been sunk across the two other principal channels to divert more water into the South Pass. The navigation channel has already enlarged, and the original depth of 8 feet has been increased to 20 feet. It is anticipated that the scouring action will be still more effectual when the jetties are completed, and that, if a bar should tend to form at the sea end of the channel, an effectual remedy could be provided by the gradual extension of the jetties seaward at a moderate cost.

Though movable dams or weirs across rivers cannot be regarded as new inventions, having been for many years extensively employed on French rivers, and an instance being recorded of the erection of a movable dam in America in 1818, where they are now being gradually introduced,[4] they are little known except in the simplest form in this country. M. Boule has designed a new form of dam,[5] which he considers specially suitable for dams higher than 12 to 14 feet, the limits of the Poirée spar or needle system and of the turning floodgate of M. Chanoine. In M. Boule's design the shuttles are placed in tiers, between slight wrought-iron upright supports, 3½ feet apart, carrying the foot-

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. li., p. 367; [2] vol. xlii., p. 278, vol. xlvii., p. 369, and vol. li., p. 361; [3] *post*, p. 367; [4] vol. l., p. 216; [5] vol. xliv., p. 268.

path, so that the shuttles can be readily removed and replaced. In America shuttles hinged at the bottom, maintained in their places by props, and falling down flat on the apron of the weir when the props are removed, have been introduced. A somewhat similar principle has been adopted for some movable dams on the weirs Vizézi and Moingt;[1] but in these dams the central pile supporting the shuttle is propped up, and the shuttles are composed of several boards laid horizontally, which can be removed successively, if the instantaneous removal of the whole dam, by releasing the prop supporting the central pile, is not necessary. A sluice-gate formed of narrow horizontal jointed boards like a shutter, and winding up round a roller, has been put up at the weir of Notre-Dame-de-la-Garenne,[2] on the river Seine. In the Mérienne dam on the Charente,[3] by omitting the upper portion of the lower cheeks of the grooves in which the shuttles slide, the shuttles, when lifted to a certain height, being hinged to the racks, rise by the pressure of the flood-waters towards a horizontal position, sinking again into their places when the flood has abated. A self-acting shutter for maintaining a constant head is described by Signor Nicorini.[4]

French engineers have devoted considerable attention to the flow of rivers, and several valuable papers have been written on this subject,[5] especially with reference to the Seine. The floods of the Po have also been carefully observed and recorded during the present century,[6] furnishing important evidence of a gradual rise in the flood level. By a careful study of the Seine basin, and the flow of its tributaries, and by means of extensive daily rainfall observations, the late M. Belgrand has been able to predict at the beginning of the summer a drought in the autumn, and to forecast the rise of the Seine in flood time at Paris so as to give timely warning to the inhabitants along its banks. On the 14th of March, 1876, M. Belgrand announced that the Seine, which was in flood, would reach a definite maximum height at Paris on the 17th of that month; and his prediction was fulfilled within half an inch.[7] Floods of the tributaries of the Seine have been similarly predicted, and in the opinion of M. Belgrand the same system might be applied with success to many other rivers. The Author considers that a similar study of the flow of rivers in this country

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liv., p. 300; [2] vol. liv., p. 297; [3] vol. xlviii., p. 311; [4] vol. xli., p. 253; [5] vol. xxxix., pp. 364 and 365, vol. xlii., p. 275, and vol. xlvi., p. 299; [6] vol. liv., p. 300; [7] vol. xliv., p. 262, vol. xlv., p. 308, and vol 1., p. 221.

would furnish valuable information, at a time when the prevention of summer floods is becoming, in many districts, a matter of pressing importance.

The Ar-men lighthouse[1] is being constructed on a reef of rocks near the Isle of Sein. The low level of the Ar-men rock on which the lighthouse rests, the rapid run of tide across the reef, and the exposure to the wind, rendered the foundations peculiarly difficult to put in; and the work was only accomplished by the energy of the native fishermen, who undertook the hazardous task of drilling the holes in the rock for receiving the iron dowels, to which the foundation courses of masonry were subsequently secured.

In this brief notice the Author has merely touched upon a few out of the many descriptions relating to public works abroad which have appeared in the Abstracts; but he trusts that those he has selected will suffice to show, that much may be learnt from a study of the practice and progress of public works engineering abroad, and in particular from the Americans in the matter of steel bridge construction, and from the French with reference to rivers.

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liv., p. 307.

No. 1,602.—"On the Progress of Machinery in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By DANIEL KINNEAR CLARK, M. Inst. C.E.

IN the department of mechanical engineering, steam machinery occupies the first place in magnitude and importance; and the records of research, embodied in the Abstracts, afford evidence of the assiduity and success with which foreign engineers and philosophers have prosecuted their investigations into the generation and performance of steam as a motive power. First in order comes M. G. A. Hirn, who has, during upwards of twenty years, occupied himself with experimental inquiries into the action and behaviour of steam in the steam engine, in which he has been ably assisted by his associates. He accurately appreciates[1] the powerful and almost instantaneous operation of the walls of the steam cylinder, and their action on the steam, for every individual stroke of the piston. A portion of the steam, when cut-off for expansion during the remainder of the stroke, is condensed as it enters the cylinder, and is, to a greater or less extent, reconverted into steam, towards the end of the expansion and during the exhaust. This action and re-action are augmented as the period of expansion is increased; and the loss of efficiency in one direction overbalances the gain of work in the other, when steam is worked expansively beyond given moderate limits.

M. Mallet[2] gives an interesting historical summary of experimental investigation, reaching back to the year 1856, into the existence of such alternate condensation and re-evaporation of steam in the cylinder.

M. Hirn has reduced the process of test experiments on steam engines to a system remarkable for precision and for the success with which the mechanical equivalent of heat is employed as a factor. He employs a thermo-dynamic formula, in which two series of quantities are to be equated. On the one side, there is the whole of the heat supplied to the engine, comprising the heat of the steam, taken as dry, passing into the cylinder, the heat conveyed by primed water, and the heat given up by the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlvii., p. 376; [2] vol. liii., p. 357.

steam condensed in the jacket. On the other side, there is the heat converted into work, the heat lost by radiation from the jacket, and the heat delivered to the condenser. M. O. Hallauer applies this formula to the results of many trials of Woolf engines and single-cylinder engines;[1] and the valuations agree, within from $\frac{1}{2}$ to 1 per cent. of error:—affording powerful evidence of the reality as well as the utility of the mechanical theory of heat.

M. Hallauer contributed the results of observations and experiments towards a solution of the question of clearance-space, in relation to the compression of exhaust steam, and its bearing on the efficiency of steam in the engine. He argued,[2] from the evidence of indicator-diagrams, in the case of an ordinary Woolf engine, that there was a gain of 10 per cent. of efficiency by the compression of the exhaust steam, as against the absence of compression: a deduction which he was enabled subsequently to corroborate by direct proof,[3] in the case of a Woolf engine, of which the valves were so modified as to augment the period of compression, in the first cylinder, from $\frac{1}{10}$ of the stroke before alteration to $\frac{1}{4}$. The economy effected by this alteration amounted to from $3\frac{1}{2}$ to $6\frac{1}{2}$ per cent. What the radical difference of efficiency may be, due to conditions of clearance and non-clearance, is not finally settled. M. Hallauer maintains, after all, that a single-cylinder beam-engine, with four valves (Corliss fashion, in which the clearance-space is minimised), and steam-jacketed, may be at least as economical as a Woolf engine or a receiver engine. The results of this experiment go to prove that for compound engines, the actual ratio of the total expansion should not exceed from 1 to 5 to 1 to 7.

M. Farcot,[4] following up the principle of the Corliss type, constructed a direct-acting pumping engine, in which the valves of the steam-cylinder were so closely adjusted that the total clearance at each end of the cylinder was not 1 per cent. of the working capacity of the cylinder. The cylinder was jacketed with steam direct from the boiler; the fuel consumed was found, by careful trials, not to exceed 1·543 lb. of coal per indicator HP. per hour. Supposing that the water had been evaporated at the rate of 8 lbs. per lb. of coal, this consumption would correspond to 12·34 lbs. of water per indicator HP. per hour:—a performance probably

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliv., p. 293; vol. liii., p. 355; [2] vol. xlii., p. 330; [3] vol. liii., p. 355; [4] vol. liii., p. 364, and vol. liv., p. 335.

unparalleled. It must be added, nevertheless, that a beam Woolf engine in regular work at Ghent, tested by M. Dwelshauvers,[1] was proved to be capable of developing 391¼ indicator HP., with a consumption of only 14·63 lbs. of water per indicator HP. per hour, and of coal 1·94 lb. Also, a pair of compound rotative beam pumping engines for the waterworks at Lawrence, Mass., when tested for performance,[2] consumed just 14 lbs. of water per indicator HP. These performances—one of a Corliss engine, the others of Woolf engines—may be accepted as amongst the best of their kinds, and they may be taken to show, in corroboration of M. Hallauer's conclusion, that no decided pre-eminence, in point of efficiency, can be claimed for one type of engine over the other.

It is further made manifest from the experiments of M. Hirn and his associates, that steam may be worked at least as efficiently in a single cylinder without a steam jacket, when superheated, as when worked in its ordinary state of saturation, either in a Woolf engine or in a single cylinder steam-jacketed.[3] This is a valuable practical conclusion, which, though it has been vaguely anticipated, has not hitherto, in England, been brought to the test of direct comparison.

It is indicated by the results of experiments made by Mr. Isherwood,[4] that a very moderate degree of super-heating suffices to secure the economy that may be effected by the substitution of super-heated steam for ordinary steam in the cylinder.

Mr. Charles E. Emery reports the results of experiments with the U. S. steamers, the 'Bache,' the 'Rush,' the 'Dexter,' and the 'Dallas,' in which the performances of single cylinders and compound cylinders were compared, and the action of the steam-jacket was tested.[5] With the 'Bache,' a reduction of consumption of water of from 11 to 12 per cent. by the addition of the steam-jacket, was effected, whilst the tendency of the evidence was to show that the compounded cylinders were more economical than the second cylinder taken alone. But the superiority of the compound system was, perhaps, more clearly put in evidence by the results of the trials with the other steamers. Comparing the 'Rush,' having compound steam-jacketed cylinders, with the 'Dexter,' having a single cylinder, felted and lagged, steam of about 80 lbs. total pressure having been employed in both cases, the most economical ratio of actual expansion in the 'Rush' was 1 to 6¼,

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liii., p. 353; [2] vol. xlvii., p. 353; [3] vol. liv., p. 335; [4] vol. liv., p. 336; [5] vol. xl., p. 292, and vol. xli., p. 296.

whilst in the 'Dexter' it was only 1 to 3½; and, in the 'Rush,' the consumption of steam was 23 per cent. less than in the 'Dexter.' This was the total economy, and, from the evidence with the 'Bache,' it may be estimated that half of this, or 12 per cent., was due to the action of the steam-jacket, and the remainder, 11 per cent., to the benefit of the division of expansive work between two cylinders. These inferences must be taken as limited to cylinders having the proportions of those on board the individual steamers, and they do not invalidate the general conclusion already drawn, from the results of continental experience.

The variation of the internal resistance of steam engines with the whole work done, has been experimentally elucidated by M. Walther-Meunier,[1] who tested a horizontal Woolf engine, with bedded cylinders, at the mills of MM. Dollfus, Mieg, & Co. When the engine developed, in the cylinders, 95·5, 131·3, and 191·3 indicator HP. successively, the power of the brake was 81·9, 86·3, and 89·1 per cent. of the indicator power respectively. It therefore appeared that the internal resistance of the engine rose slowly from 17·3 to 17·9 and 20·9 indicator HP.; and that in doubling the total indicator power, the internal resistance was augmented by 3·6 indicator HP. only. These data may serve to correct some erroneous assumptions with respect to the rate of augmentation of internal resistance, which, in this instance, is unexpectedly low, and which at full power did not exceed 11 per cent. of the total indicator power.

The value of the mechanical equivalent of heat continues to be a subject of inquiry. M. G. A. Hirn[2] tested it by four independent series of investigations:—of the friction of water, of the flow of water under high pressures, of the crushing of lead under a ram, and of the fall of temperature due to the expansion of air. On the evidence, taken together, M. Hirn concluded that the most nearly correct value of the equivalent was 432 kilogrammètres per calorie, or, in English measures, 787·4 foot-pounds per heat-unit. At the same time, he retained for use the value 425 kilogrammètres (or 774·70 foot-pounds), which has been adopted by most continental authors on the theory of the mechanical equivalent of heat. It may be stated, in this connection, that the Committee of the British Association for determining the value of the mechanical equivalent have reported that 772·55 foot-pounds, subject to some small correction, is the equivalent at the sea-level. This value is confirmatory of the old unit, 772 foot-pounds. Never-

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. l., p. 260; [2] vol. xliv., p. 29.

theless M. Violle[1] deduces from the results of many experiments made by him with a gyroscope revolving between the poles of an electro-magnet, the quantity, 790 foot-pounds, as the true mechanical equivalent: a value which differs little from that deduced by M. Hirn.

M. Paul Havrez[2] endeavoured to reduce to a geometrical ratio the law of the decreasing evaporative performance of the heating surface of steam boilers, as it recedes from the furnace. His deductions were based on the results of experiments by Mr. C. W. Williams and Mr. John Graham, and the more recent experiments of M. Petiet and others in France, on locomotive boilers. M. Petiet's experiments showed, that the surface of the firebox,—exposed to radiated heat from the fire,—evaporated per unit of surface by far the largest proportion of water, and that the efficiency of the boiler surface was rapidly reduced, advancing towards the smokebox, insomuch that the evaporation was diminished by one-half for each interval from yard to yard; that is to say, each lineal yard of tubes evaporated only half the quantity of water per hour that was evaporated by the preceding yard.

M. Paul Havrez also formulated the results of a long series of observations made by himself and his brother, with the object of determining the best proportions of boilers.[3] He developed many novel and interesting relations between power, surface, capability, and weight of boilers of different classes, which, whether they are to be taken as final or as provisional, throw much light on some of the hitherto occult properties, with respect to efficiency, of steam boilers of various types. In the second part of his investigations,[4] M. Havrez, led, to some extent probably by the results of his prior investigations on the efficiency of evaporating surface,[5] advocated a species of boiler which may be called, "united boilers" (*Chaudières accolées*), in which he employed, to the largest possible extent, direct heating surface over a spacious furnace, with a large and extended central flue, surrounded by boilers and heaters.

The comparative merits of Lancashire boilers and French or elephant boilers, formed the subject of a course of experiments instituted by the "Société Industrielle de Mulhouse."[6] The results of the experiments showed a remarkable identity of performance of the two boilers, both as to evaporative performance and as to

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xl., p. 362; [2] vol. xxxix., p. 398; [3] vol. xlii., p. 322, and vol. xliii., p. 368; [4] vol. xliii., p. 375; [5] vol. xxxix., p. 398; [6] vol. xliii., p. 377.

efficiency of fuel; and they tended to prove that plate heating-surface would do the same duty for evaporation, whether presented in one form or in another. The reporters concluded that, regarding economy of result, the design of the boiler was of little consequence, and that the truly important point was to provide large heat-absorbing surface in relation to the coal burned. The second part of the conclusion was in accordance with the continental taste for extensively developed heating surface, without taking into consideration the area of the firegrate.

It has been shown by the results of comparative experiments made by Professor Thurston, that wet tan-fuel can be successfully burned under steam boilers.[1] It was proved that, for the best action, the fuel required to be dried under the cover of firebrick ovens, the heat retained, and the combustion completed, before the gaseous products touched the surface of the boiler; and that, for the same object—the retention of the heat—the grate should be of firebrick. A boiler and furnace constructed according to these provisions, evaporated 1·74 lb. of water per lb. of wet tan; whilst in other boilers, where the same fuel was deposited on ordinary cast-iron grates, and burned in contact with the boiler surface, only 1·16 lb. of water was evaporated per lb. of wet tan.

Similar treatment has been found beneficial for the combustion and utilisation of powdered fuel under steam boilers.[2] In the experiments made by Mr. Isherwood with powdered coal, the powdered fuel was mixed with a blast of air, and burned under a brick arch turned over the firebars. The general bearing of the experimental results showed that coal, whether anthracitic or bituminous, when pulverised for combustion, was decidedly less efficient for evaporation than the same fuel in lumps. But the inferiority here displayed probably resulted from depriving the boiler of the action of the radiant heat of combustion, by the interposition of the enveloping arch, which was removed when the lump coal was burned.

The value of a blast of compressed air for augmenting the evaporative power of steam boilers has been satisfactorily established by M. L. E. Bertin,[3] who estimated that the quantity of steam consumed for compressing a supply of air to act as a blast in the chimneys of steam boilers amounted to only one-tenth of the quantity required when discharged as a blast, direct into the chimney. The power developed by the engine of the steamer

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xl., p. 347; [2] vol. xliv., p. 289; [3] vol. li., p. 324.

"Résolue" was more than doubled by the application of the compressed-air blast to the boilers, whilst the power required for the generation of the blast did not exceed 5 per cent. of the power of the engine.

In America, a spiral exhaust-nozzle has been introduced by Mr. Thomas Shaw, by the use of which the noise of steam blowing-off at the safety-valves of locomotives and steam vessels is effectually quelled.[1]

The causes of corrosion and incrustation of steam boilers have been perseveringly investigated by French engineers. M. Hétet[2] explains that the deposits which take place in steam boilers, worked with surface-condensers, consist of iron-oxide and acid fats, forming ferruginous soaps containing 50 per cent. of iron, and that the iron is obtained by internal corrosion of the boiler. He employed a chalk mixture to neutralise the acid, and so arrested the corrosion of the boiler[3] and the formation of deposits there. M. Allaire[4] contends for the substitution of refined neutral oils, which are chemically harmless, and are totally consumed in the cylinder without suffering decomposition or generating deposits. M. Stapfer[5] also proposes the use of mineral or neutral oils for lubrication, although he notices that a stiff gum-like substance may be formed, analogous to caoutchouc, which adheres to the piston-rod.

M. Audenet[6] suggests that a species of trap should be placed at the entrance from the exhaust-pipe to the condenser, for the interception of greasy impurities. He estimates, from the results of observations made on the surface-condensers of the "Dives," that the quantity of heat which passed through tube-surfaces when new, amounted to 500 units per square foot per hour per degree Fahr. difference of temperature. But he recognises that this value must be diminished by deposits of fatty matter, and he alludes to the consequent loss of vacuum in transatlantic steamers fitted with surface-condensers, amounting to from 1·20 to 2·40 inches of mercury during the double voyage out and back.

For the prevention of incrustation, zinc[7] and talc[8] have each been used in steam boilers. The effective action in each case is mechanical in its nature. With zinc, according to M. Lesueur, a decomposition of water takes place, by which the zinc is oxidised whilst free hydrogen gas is discharged from the surface of the iron plates of the boiler, and baffles, in a greater or less degree, the

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. li., p. 325; [2] vol. xliv., p. 284; [3] vol. lii., p. 365; [4] vol. liii., p. 399; [5] vol. xlvii., p. 372; [6] vol. xxxix., p. 399; [7] vol. xlii., p. 329; [8] vol. liii., p. 352.

deposition of scale on the surface. It does not appear that much is to be hoped for from the zinc process; but the talc process promises better. Pulverised talc has been employed successfully in locomotive boilers on the Paris and Lyons railway, and, whilst it prevents incrustation, it has also the effect of reducing the friction of the pistons and the piston-rods. Its action appears to be purely mechanical; in virtue of its scaly structure, it presents a great extent of surface, offering many points of attachment for the salts of incrustation.

MM. Béranger and Stingl[1] have arranged a process of preliminary purification of the feed-water of boilers, in which the inorganic elements of impurity are precipitated by chemical treatment, and the water is decanted and filtered prior to its being delivered to the boiler.

The theory of furnace chimneys has been discussed by continental writers. Whilst Signor P. Guzzi[2] assumes that the draught increases with the temperature at all temperatures, M. Cornut,[3] who is probably in the right, maintains that the draught, though it increases at first with the temperature, diminishes with the higher temperatures, and that it reaches a maximum when the temperature amounts to 560° Fahr., taking the external air at 50° Fahr. Mr. Robert Briggs[4] gives a useful formula for the sectional area of chimneys for steam-boilers.

In the practice of locomotives, attention continues to be directed to the development of full-power engines. Herr Steinsberg,[5] in conjunction with Herr Schau, designed and employed an eight-wheeled coupled engine for the traffic of the Poti-Tiflis railway. The wheel-base was limited to 10 feet 8 inches, when employing wheels of only 1 mètre in diameter. Radial axles were not employed, but the leading and the trailing axles were simply free to move laterally. In a posthumous memoir, by M. Le Chatelier[6] he recommends the employment of two engines coupled together for mountain traffic, but he omits to point out how they should be connected, so that they may not baffle each other. For the satisfactory solution of the problem of full-power engines, flexibility of base, combined with radial axles, must be recognised as necessary elements. The principle of the double bogie, already worked out in England by Mr. R. F. Fairlie, has been applied by M. Rarchaert[7] in a locomotive, which is placed on two four-

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liv., p. 331; [2] vol. liii., p. 350; [3] vol. l., p. 268; [4] vol. xlvi., p. 339; [5] vol. xxxix., p. 335; [6] vol. xxxix., p. 342; [7] vol. xlix., p. 312.

wheeled bogies. The wheels of the bogies are coupled, and the bogies are also coupled together by a central coupling-rod under the boiler, to which the power of a single pair of cylinders is communicated through a transverse crank-shaft. Compared with an ordinary six-coupled-wheel engine, the relatively slight wear of the wheel flanges attested the greater freedom of the Rarchaert engine on the rails. It also employs the whole of the weight for adhesion, with one pair of steam-cylinders.

The central-rail locomotive for mountain traffic, as described by M. Desbrière,[1] has been gradually improved; although it remains a question to be settled by experience, whether two cylinders or four cylinders should be employed. In the engines of this kind, constructed for the Cantagallo railway, Brazil, by the introduction of a few obvious and simple modifications the breakage of the machinery, frequent in engines of an earlier class, have disappeared; whilst in other engines, for New Zealand, the dispersion of oil from the interior machinery upon the surfaces of the central rail, has been entirely prevented by the application of a shield.

To diminish the wear of the flanges of the leading wheels of locomotives tablets of grease, or of felt saturated with oil, have been employed in Bavaria with success; applied so as to lubricate the flanges.[2] It has been observed that the duration of the flanges is increased 50 per cent. by the lubrication.

That the link-motion of Stephenson is not likely to be superseded for the valve-gear of locomotives, has been proved by the results of a long series of experiments conducted by Professor Bauschinger on a Bavarian railway.[3] Testing the comparative merits of the link-motion and Meyer's valve-gear, the water consumed per HP. per hour was 37·4 lbs. with Meyer's gear, whilst with the link-motion it did not exceed 30½ lbs. The consumptions of fuel were proportionally different. The comparative economy effected by the use of the link-motion is ascribed—and, with much probability, justly ascribed—to the compression of exhaust steam, which takes place in cylinders fitted with that motion.

Continental railway engineers are taking active steps for preserving the boilers of locomotives. On the Thuringian lines of railway, the feed-water, derived from the limestone and gypsum rocks, has for some time been purified by treatment with chloride of barium and caustic lime, in settling tanks.[4] An experimental trial

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlvii., p. 331; [2] vol. li., p. 315; [3] vol. xl., p. 280; [4] vol. xli. p. 292.

of Herr A. Feldbacher's invention for preventing incrustation by lining the boiler with sheet copper, was made in a shunting engine at the Vienna terminus. The result of the trial showed that the system was completely successful in preserving the plates from incrustation and from corrosion.

Steam-power has been substituted for the power of horses on light railways, with great economical advantage. At the iron works at Decazeville [1] the cost has been reduced from 2·41*d.* per ton conveyed per mile by horses, to 1·56*d.* by locomotives. Similarly, in the coal mines at Doman,[2] in Hungary, the cost has been reduced from 2*d.* per ton of coal drawn by horses, to a little over 1*d.* per ton drawn by locomotives.

The introduction of compound cylinders for locomotives, by M. Mallet,[3] on the Bayonne and Biarritz railway, is a new departure in the improvement of locomotives, which lend themselves readily to the compounding of the cylinders. It does not appear from the results of performance hitherto made public, that there is any distinctive economy of consumption in the compounded locomotives. The absence of economy is the natural consequence of the absence of steam-jackets or superheating apparatus. Meantime, M. Mallet has demonstrated the feasibility of the compound system in locomotives; economy will no doubt follow. In the same Paper, M. Mallet summarises the investigations of various experimentalists on the action and behaviour of steam in the cylinders of locomotives.

According to an exhaustive report on the system of warming railway carriages in England and on the Continent,[4] there is great diversity of opinion as to what constitutes the best system; though it is acknowledged that, in England, the common foot-warmer is by general consent accepted as satisfactory, whilst it is the least expensive system. The reporter agrees in this conclusion.

The results of test-trials of turbine water-wheels, on the Continent and in America, appear to establish the superiority of the inward-flow kinds of turbine, originally designed by Professor James Thomson. Of these, the best recorded performance is that of a Swain turbine, 72 inches in diameter, having a maximum gate of 13 inches, at Boott Cotton Mill, U.S.[5] The turbine was tested by Mr. J. B. Francis. In the Swain turbine, the discharge is inward and downward. The receiving edges of the floats of the

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. l., p. 246; [2] vol. l., p. 247; [3] vol. li., p. 314, and vol. liii., p. 357; [4] vol. li., p. 316; [5] vol. xli., p. 334.

wheel are vertical, opposite the guide-blades, and the lower
tions of the edges are bent into the form of a quadrant.
float thus forms, with the surface of the adjoining float, an
which combines an inward and a downward discharge. A
mum efficiency of 84 per cent. was attained with a 12-inch
with a 9-inch gate an efficiency of 83 per cent was attaine
half-gate, 78 per cent.; and at quarter-gate, 61 per cent.
performances, taken together, are unrivalled by any othe
formance recorded in the abstracts. Girard turbines,—tang
wheels specially suited for very high falls,—are employed
works of the St. Gothard tunnel.[1] They have a diameter of
10½ inches, and they make 160 turns per minute, with a maxi
charge of water of 67 gallons per second. They are remarkab
the unprecedented head—279 feet—under which they are wo

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlii., p. 240.

No. 1,624.—"On the Progress of Mining and Metallurgy in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By HILARY BAUERMAN, Assoc. Inst. C.E.

THE subjects included under the above comprehensive heading are so very numerous, and the space available for their consideration necessarily so small, that the record must be regarded as in the main a fragmentary one. This is also to some extent conditioned by the unequal character of the works consulted, some of them, among which the "Annales des Mines," the "Zeitschrift für Berg- Hütten- und Salinenwesen," may be mentioned as types, being Government publications, and containing only original memoirs, illustrated in the most complete and costly fashion; while others, being private periodicals without State support, are necessarily compelled to reproduce many articles that have appeared elsewhere, either in the same or in foreign countries. This is now becoming very much the rule with English and American memoirs, which are frequently translated for the benefit of German readers.

In regard to mining in its most characteristic element, that of breaking ground, the chief noticeable features are the gradual introduction of machines in substitution for hand-boring, and the increasing popularity of the more powerful explosives, dynamite and other nitroglycerine preparations, over ordinary blasting powder. The use of the former has been chiefly confined to the largest class of railway tunnels, such as the St. Gothard,[1] Cochem,[2], Elm Gemünden and Bebra-Friedland lines in the Thüringer Wald,[3] and Sonnenstein[4] on the Gemünden-Ischl line, and in the completion of the deep adits at Schemnitz,[5] and Rothschönberg at Freiberg, and the Sutro tunnel in Nevada. As might be expected from the success achieved by the original machine of Sommeillere in the Col de Frejus tunnel, it has in its newest developments, those of Ferroux and Dubois and François, remained in considerable favour for other works of a similar character, the latter being in special favour in Belgium and the collieries of the North of France, although in the latter district great ingenuity has recently been manifested in the direction of simplification,

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxix., p. 325, 408; [2] vol. l., p. 241; [3] vol. l., p. 243; [4] vol. li., p. 342, vol. liii., p. 368; [5] vol. xlii., p. 293.

especially in the turning gear. In America and this country other patterns, of American, English, and German origin, were in favour, but there seems no good reason as yet to assign any decided preference to any one pattern, many being, so to speak, of almost equal excellence; and the results achieved depend as much on correct organisation and drill of the working staff, as on the specific merit of any particular machine. An analysis of different systems of boring machines, by A. Pernolet,[1] and a somewhat similar one by Dr. Hartig,[2] are the most generalised communications upon the subject. A later compendium of information, comprising notices of the various power drills at the Philadelphia Exhibition,[3] may be mentioned here. It has been excluded from the Abstracts as being an Exhibition report. Of more special interest is Brandt's system[4] of boring by a rotary saw-cutting steel tube, pressed up to the work by a heavy hydraulic pressure. This was employed in the Sonnenstein tunnel of the Gemünden-Ischl line, mainly in hard limestone. This exceedingly ingenious machine has attracted considerable attention, and has been fully illustrated in the technical journals of almost every country in Europe. It is said to be equally effective in harder rocks, but no trials on such rocks have yet been made, at least to any extent.

In deep boring for mineral explorations, the principle of continuous flushing, so as to present a clean face to the tool to operate upon, whether by percussive impact or by rotation under pressure, is coming more and more into favour. This principle, which was first used by Fauvelle,[5] has been adopted in the diamond-boring system, and in a new method, originating in Denmark, known as the Aalborg system, where in sinking through loose ground no cutting tool is used, the detritus being forced up between an inner and outer tube by a jet of water under pressure. This has been much used on the flat land of Holstein and Jutland for water wells;[6] and in the colliery district of Westphalia with various kinds of cutting tools in loose strata overlying the coal measures, which have been bored through at the rate of about 100 feet per day.[7] Of the numerous borings executed with the diamond-borer on the Continent, two of the most remarkable, made in Bohemia[8] and at Rheinfelden in Switzerland, have attracted considerable attention. The latter has been described in full detail, together with one of

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xli., p. 263; [2] vol. xli., p. 265; [3] Oest. Zeitschrift für Berg- und Hüttenwesen, vol. xxvi., p. 3; [4] vol. li., p. 342; liii., p. 368; [5] vol. xx., p. 298, and vol. xxiii., p. 462; [6] vol. xlv. p. 320; [7] vol. xlv., p. 327; [8] vol. xliii., p. 401.

almost exactly similar depth and dimensions made at Malkowitz in Bohemia, with the ordinary system of rods and free-falling cutting tools, the results being used in a careful comparison of the two methods.[1] The American system of rope-boring for petroleum wells is described by Dr. Althans,[2] in one of his official reports to the Prussian Government on the results of the Philadelphia Exhibition.

In certain special cases the use of dynamite for the removal of obstructions in borings has been resorted to with varying success. The most interesting example is probably that at Goisern,[3] where a broken tool was shattered and loosened after various attempts at detonating the charge had failed; owing to some anomalous behaviour in the explosive agent under the great pressure to which it was subjected. An American system of shaft sinking, by drilling a series of parallel holes with a diamond drill to a great depth and blasting them away in lengths, has been tried at Saarbrücken,[4] and at Poremba in Upper Silesia.

As regards the properties of explosives, the contributions refer principally to dynamite, several communications on the composition and behaviour of this substance, by Hess,[5] having appeared in the "Austrian Artillery Journal." In Sweden,[6] dynamite and nitroglycerine have been chiefly of service in diminishing the number of bore-holes required; but at Přibram,[7] considerable saving in time, labour, and cost appear to have resulted from its adoption, the best results being only obtained with electric ignition, the saving being sensibly lower when fuse and detonating caps are used. This coincides substantially with what has been observed in England.

The problem of machine cutting does not appear to have attracted much attention in foreign countries, the principal contributions having reference to a modification of the rotatory coal cutter of Winstanly and Barker, which has been used at Ostran[8] for coal, and in the Wieliczka mines[9] for salt. In the latter case it is found to be chiefly advantageous in diminishing the amount of small salt and the number of irregularly shaped lumps.

In most of the machines previously mentioned compressed air is employed as a motive power, and the increasing extension of the use of this agent has made its economic production a question of

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liv., p. 357; [2] vol. li., p. 339; [3] vol. liv., p. 355; [4] vol. xlvi., p. 351; vol. xliv., p. 287; [5] vol. xlvi., p. 368; vol. xlviii., pp. 363–364; vol. lii., p. 391; [6] vol. xlix., p. 108; [7] vol. liv., p. 361; [8] vol. l., p. 236; [9] vol. lii., p. 362.

considerable importance. Prominent among the investigations of this subject are those of M. Cornet,[1] of Levant du Flenu, Belgium, who has succeeded by the use of single-acting compressors, with very finely divided water injection, in nearly realizing the theoretical effect of his engine; and subsequently, by the same method of injecting water, in working air engines underground with a high degree of expansion without the formation of ice in the cylinders, the water used being at the temperature of the mine, or from 70° to 80° Fahr.

The working of mineral deposits, being of special rather than general engineering interest, has not received much notice. Two examples have been considered as presenting peculiarities worthy of record; the first of these is at Dombrowa,[2] in Russian Poland, where a seam of about 30 feet thick is entirely worked without leaving pillars or using packing of any kind; and the second at Davidsthal,[3] in Bohemia, in a thick seam of lignite, where a similar method, but using earth packing for the excavated spaces, is followed.

Among the numerous examples of new deep winnings and the extension of old mines to great depths, the most interesting are those of Přibram and Clausthal among metalliferous mines, and the large collieries belonging to the Prussian Government near Gleiwitz, in Upper Silesia. The latter are laid out on a scale comparable with the largest collieries in the North of England and Lancashire, for an output of 3,000 tons and upwards per diem; the plant is for the most part similar to that used in England. At Přibram the enduring ore-bearing quality of the principal lode, which is nearly vertical, has led to an extension of the workings to a depth of rather more than 1,000 metres below the surface, it being now the deepest mine in the world. This great depth necessitates the use of steam power both for drawing minerals and for conveying the men to and from their work. The engines for the former purpose are of a direct-acting horizontal pattern with cylindrical drums, and drawing with tapered round steel ropes, the calculations that have led to the adoption of this pattern being given in detail with the description.[4] These refer to the special case of a small load drawn from a great depth at high speed, and are therefore not applicable for the ordinary case of colliery working. Information as to the wear of these ropes when compared with those of soft iron wire, has also been given

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlix., p. 352; [2] vol. xlvi., p. 346; [3] vol. xlvii., p. 383; [4] vol. xli., p. 270.

in a subsequent paper.[1] The man engine in connection with the same mine is also noticeable as being the largest example of its class. It has been for some years in use, down to a depth of nearly 800 yards; but the development of deeper workings calling for an extension to beyond 1,000 yards, it is being entirely reconstructed in solid steel,[2] without bolt holes or perforations of any kind to reduce the strength of the rods. At Clausthal[3] a man engine of the ladder construction, *i.e.*, with rods made of parallel iron bars with platforms between them, has been established to the lesser depth of 712 yards, in connection with the new workings below the deep adit. These are interesting, as they will probably be among the last examples of their class; as the adoption of more powerful winding machinery and improvement in the drawing arrangements in the shafts, are in most instances leading to the substitution of cages for raising and lowering the miners, in preference to other methods.

In pumping machinery, the tendency of recent improvement has been towards the substitution of high-speed rotatory engines for the older single-acting form with reciprocating rods, and much ingenuity is also displayed in contrivances for doing away with rods altogether. Of the examples recorded that at Föhnsdorf, in Styria,[4] is generally similar in arrangement to the earlier direct-acting rotatory engines erected underground in this country, except that ball valves are used in the pumps. It is placed about 210 yards underground, taking steam from boilers at the surface about 240 yards distant, and under the local conditions, is computed to have cost about £4,000 less than a direct-acting engine drawing with rods would have done.

The engine at Rossitz[5] in Moravia is a remarkable contrast to the preceding, as representing an older form of construction, carried out in the simplest possible form and on a very large scale. It is direct-acting, with a steam cylinder 90 inches in diameter, standing upon bridge girders above the shaft, with a main rod of a box girder construction in wrought iron, weighing 125 tons. The plunger pumps, of 18 inches diameter, have so-called compensation tubes, that is, the water is forced about 62 feet higher than the cistern of the next high pump-lift, and gives out a portion of the work so absorbed on the return stroke. The use of glycerine instead of water in the cataracts, to ensure their action in frosty weather, is also noticeable as a novelty.

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlvii., p. 403; [2] vol. liv., p. 340; [3] vol. xlvi., p. 340; [4] vol. xlviii., p. 341; [5] vol. xlv., p. 349.

Darlington's method of working pump by a solid mass of water instead of a pump rod, has been tried on a considerable scale at the mine of Sulzbach Altenwald, in the Saarbrücken coal-field,[1] where a pair of horizontal steam engines drive two corresponding pairs of pumps at the bottom of the mine, 303 yards deep, by two lines of pressure tubes, through which water, freed as much as possible from air, circulates from the engine pumps to those below, and returns. The arrangements adopted for keeping the pressure tubes filled with water, and several other details of construction, are of an ingenious character, and a fair duty has been realised; but the success does not appear to be such as to lead to the supposition that the experiment will be often repeated.

At Clausthal[2] a somewhat similar expedient to the preceding has been adopted in the construction of water-pressure engines in connection with the new deep workings, which are intended to drain a large number of adjacent mines by a communicating level, and so supersede many old-fashioned lifting pumps worked by water-wheels and wooden rods. Here, in order to do away with the use of reciprocating rods, the engines are placed at the bottom of the mine, nearly 2,000 feet below the top of the driving column, and 750 feet below the point at which the discharge takes place. This arrangement involves a back pressure of nearly 400 lbs. upon the square inch on the working surface of the piston above that due to the driving pressure. Such great pressures forbid the use of air vessels for relieving the shocks at the change of stroke, which are avoided by making all the water-ways in the valve boxes and the piston-packings systematically leaky, so that there is a considerable loss of water when the direction of motion is reversed—a point which, under the particular condition, is not of any moment, the water supply being more than sufficient for the work to be done; but it is apparent in the very low duty realised, only 25 per cent. of that of the gross power due to the fall when at the maximum speed, and much less when making a smaller number of revolutions. The cost of the engines, about £15,000 for less than 100 HP., is considerable; this is mainly due to their being constructed in bronze and gun metal. But the experiment is a remarkable one, although not likely to be imitated in many places, owing to the special conditions of the locality, where a considerable hydraulic head has been created by a deep adit level.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xl., p. 294; vol. xliii., p. 404;
[2] vol. xlv., p. 347; vol. liv., p. 342.

Probably some of the deep workings in the Comstock lode, in connection with the Sutro tunnel, might be suited to a similar combination.

In the construction-of-pump work the telescopic pump of Rittinger,[1] where the plunger and delivery tube rod are combined in one piece, has of late come into considerable favour with foreign engineers. This form of pump is especially suited to double-acting rotatory engines, where the rods are always in tension, and allows an engine of considerable power to be made of sensibly smaller dimensions than a single-acting engine of the same power; a notable example being furnished by the engine of 300 HP. shown in motion at the Paris Exhibition by the Société Cockerill, of Seraing. Rotatory Woolf engines of a similar kind, but of much larger dimensions, are in use at Bleiberg, Vielle Montagne, and other Belgian and Rhenish mines; a colossal example being furnished by an engine at a colliery at Bascoup, in Belgium, of 1,200 HP., with fly-wheels, whose rotatory mass can be varied up to a maximum of 80 tons. In another type, by Hr. Kley, of Bonn, cataract gear is adopted, so that the engines, although rotatory, can be worked intermittently in the same way as a Cornish engine. In connection with pumping, the memoir by Hr. Mehner,[2] on the production of salt from brine wells at Schönebeck, is of interest, as describing the method adopted in drawing brine from borings of considerable depth. The method does not, however, seem suited to modern requirements; and, where a large production is intended, it would appear to be better to sink shafts and work the rock salt in mass, in preference to pumping it out in solution, which has indeed been done at the locality in question.

The use of iron in securing underground workings has been adopted as a temporary expedient in the Altenburg[3] and Rensfeld railway tunnels, and permanently in the shafts of a small mine sunk to the amber bed at Nortyken, in Samland, near Königsberg, in Prussia,[4] and in several new shafts and levels in the Saarbrücken collieries.[5] The latter memoir is of especial interest, although not giving any great amount of detail (it appeared first in a local newspaper), as showing how many different combinations have been attempted in the adoption of iron in substitution for timber. Probably more complete information will be furnished in the official journal at a future date.

In the dressing of minerals there is not much of importance to

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liv., p. 347; [2] vol. xlv., p. 332; [3] vol. liii., p. 367; [4] vol. xl., p. 342; [5] vol. liv., p. 352.

be noted, the principal communication being that relating to the coal-washing machine of M. Max Evrard,[1] of St. Etienne, in which the piston of the usual hydraulic jigger is replaced by jets of steam acting upon a water surface intermittently. This, and another form of washer, by M. J. B. Marsaut, have recently been adopted, to a certain extent, in the coal basin of the Loire. They have the advantage over the older forms of apparatus of more nearly imitating the action of hand jigging; that is, the motion may be varied more rapidly, and within wider limits, than is possible with plungers driven by eccentrics. The Brunton frame,[2] for slime dressing, has been modified in America by Mr. Frue, by the addition of a lateral shaking motion to the endless canvas belts, which facilitates the separation of the fine particles of mineral. An endless frame, in which wire netting is used instead of a canvas belt, has been introduced at a picking-table at Přibram.[3] The chief feature of interest in the technology of mineral dressing in America is, however, to be found in the large direct-acting hammer-stamps in use on Lake Superior. Several accounts have been published of these during the period under review, that to which the reference is given below being from an original American source.[4]

Before leaving this subject, it will be as well to call attention to the valuable memoir by Dr. Althans, on the progress in mineral dressing during the past century,[5] which, although unsuited for abstracting from its encyclopædic character, will be found to be of great service as a compendium of the present state of knowledge upon this important class of mechanical contrivances. It has subsequently been issued in a separate form.

The great increase in the consumption of zinc both as metal and as oxide, for roofing, paint, &c., has of late years produced considerable activity in the search for its ores, and large sums have been expended in the development of blende deposits in out-of-the-way places. Among the earliest of these, and now the most completely developed, are the great mines of Ämmeberg, in Sweden, which have been brought to a high state of production by Hr. O. Schwartzmann, of the Vielle Montagne Company.[6] Another, and perhaps more remarkable group of mines, are those of the Schneeberg, in Tyrol,[7] formerly worked for silver and lead, which have recently been opened as zinc mines by the Austrian Government.

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xl., p. 323, and *ante*, p. 259; [2] vol. xlvii., p. 401; [3] vol. xlii., p. 357; [4] vol. l., p. 280; [5] Zeitschrift für Berg-Hütten- und Salinenwesen, vol. xxvi., p. 105; [6] vol. l., p. 276; [7] vol. liii., p. 379.

Similar mountain mines, involving elaborate systems of inclined planes or wire tramways for the transport of mineral, in the Eastern Alps, have been described. These are the spathic ore deposits of the Styrian Iron Company at Eisenerz,[1] and the manganese mine of Vigunsca, in Tyrol.[2]

In metallurgy, the most prominent improvements in the smelting of iron ores have been in the direction of increased production, with proportionately diminished consumption of fuel, by the adoption of the large English type of blast furnace and large blowing and stove power. The history of the works at Gleiwitz[3] affords a good instance of the transformation of an old-fashioned plant into one more in accordance with modern requirements. The smelting of oolitic ores in Luxemburg,[4] and the working of similar ores in Lorraine,[5] are represented by memoirs of great interest, as describing the progress of districts analogous to those of Cleveland and Northamptonshire. The smelting of such ores in Belgium, and their subsequent conversion into malleable iron, has been described by M. Le Chatelier,[6] and M. Lencauchez.[7]

The Raschette form of blast furnace,[8] which has been tried at different places in Europe but not brought into general use, has been applied, with some modifications, in its original home in the Ural on rather a large scale.

A Paper on Hungarian pig iron, by Professor Kerperly,[9] is interesting, as furnishing information upon a subject of which very little has hitherto appeared.

In gas-heated furnaces, the most notable feature is the increasing popularity of the Siemens regenerative type, which has been applied to the various processes of iron and steel manufacture in districts where mineral fuel is either scarce or wholly wanting. Among these may be mentioned the cast-steel works of Kama, in Russia,[10] and those of Eibiswald[11] and Gratz,[12] in Styria; at the latter the open-hearth furnace is used, and a method of determining manganese by the peroxide of lead test appears to have been applied for the first time. Modifications of the Lundin[13] condenser, used for drying wet gas for furnace use by the substitution of surfaces for jet condensation, have been applied in Sweden, in consequence of the regulation forbidding the fouling of watercourses with tarry refuse.

The simplified construction of regenerator furnaces by Ponsard,[14]

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliii., p. 407; [2] vol. xlv., p. 330; [3] vol. xl., p. 325; [4] vol. xlviii., p. 352; [5] vol. xlii., p. 358; [6] vol. xl., p. 335; [7] vol. xl., p. 336; [8] vol. xl., p. 328; [9] vol. l., p. 274; [10] vol. l., p. 269; [11] vol. l., p. 271; [12] vol. lii., p. 6; [13] vol. xli., p. 302; [14] vol. xl., p. 330.

and the rotatory Siemens-Marten furnace of Pernot,[1] are among the more important of the other memoirs bearing on this subject. The general question of the utilisation of heat in furnaces has been the subject of a memoir by Professor Grüner;[2] and that of the possible temperature attainable, by M. Perissé.[3] The production of particular kinds of steel containing phosphorus, silicon, manganese, &c., which has been elaborated by the Terrenoire Company during the last three years, has been described by M. Euverte.[4]

A point of special interest in connection with gas firing is noticed in a memoir by Hr. Belani,[5] on the effect of dust in lowering the fuel value of blast-furnace gases; and another by Hr. Borbely,[6] on the effect of a small quantity of salt contained in sand in obstructing the passages in gas regenerators by the continuous production of ferric oxide from ferric chloride circulating in the gas. The application of Siemens' and other gas furnaces to glass-making has been discussed from a Belgian point of view by M. Tock.[7]

Of the Bessemer process there are comparatively few notices; the principal one describes the plant at two new works in Sweden.[8] These are chiefly remarkable for the application of water-power on a large scale. The most important example of this class, that at Domnarfvet, has not as yet been completely described.

In zinc smelting, a Paper of a speculative character, by M. Lencauchez,[9] on the conditions under which the blast furnace might possibly be used, is interesting as representing a class of ideas that are revived from time to time, but without making much progress. Of greater general interest is the Paper by Hr. M. Georgi,[10] on the state of the zinc industry in Silesia, which shows, among other points, how remarkably low in produce the bulk of the ores are that are smelted in the largest zinc-producing district in Europe.

In the application of zinc to the desilverising of lead, by Parkes's process, two new furnaces have been described by Dr. Wedding. One is of the ordinary Silesian pattern, but gas-heated with hot blast, and erected experimentally at Tarnowitz;[11] and the other the simplified American method of Faber du Four,[12] using bottle-shaped black lead retorts in a portable furnace.

The recent discoveries of fresh kinds of nickel ores in large quantities in New Caledonia has called attention to this metal. Novel methods of smelting, devised by M. Garnier,[13] have been to

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xl., p. 331; [2] vol. xliv., p. 310; [3] vol. xliv., p. 312; [4] vol. xlix., p. 358–360; [5] vol. xlvii., p. 390; [6] vol. xlvi., p. 331; [7] vol. xlvi., p. 334; [8] vol. xlvii., p. 388; [9] vol. li., p. 332; [10] vol. xlix., p. 369; [11] vol. xl. p. 340; [12] vol. xlviii., p. 360; [13] vol. li., p. 335; vol. lii., p. 342.

some extent adopted, and a useful memoir on the processes generally adopted (so far as they are known) has been compiled by M. Badoureau.[1]

In the metallurgy of copper the processes of wet extraction are growing in favour for the treatment of low-class ores. The chief novelty among these is the Hunt and Douglass process, used in America.[2] A modification of the cementation process, in which sulphurous acid is passed through the copper liquors in order to reduce the amount of scrap iron required for precipitation, has been introduced at the historically interesting works of Agordo, in the Venetian Alps.[3]

Finally, attention may be called to memoirs of an encyclopædic character, describing the processes carried on at several of the older European mining centres, such as Freiberg,[4] Oker, and the other establishments connected with the Rammelsberg mine,[5] and Almaden,[6] which have been more or less completely modified since the period of former descriptions. Such memoirs can, however, scarcely be done justice to even in the longest abstracts, and the reader is therefore recommended to consult them in their original forms.

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liii., p. 380; [2] vol. xlvi., p. 329; [3] vol. xlvi., p. 327; [4] vol. xlii., p. 345; [5] vol. lii., p. 347; [6] vol. liv., p. 370.

No. 1,604. "On Progress in the Application of Electrical Science to Engineering Purposes in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78." By PAGET HIGGS, Assoc. Inst. C.E.

OF all the applications of the science of electricity to practical purposes that fall within the cognisance of the engineer, telegraphy is the most important. Since the commencement of the "Abstracts" in 1874, great advances have been made in telegraphy, and that not only in one branch; whether attention be turned to the improvements upon existing apparatus and systems, or to discoveries and inventions, progress is equally marked. It is characteristic of the improvements in telegraphy that the more important excite the interest of the world; in return for this, telegraphy has perhaps done more than any other applied science towards instructing people generally in the principles of scientific engineering. Scarcely has interest subsided in the apparently wonderful fast-speed telegraphs, before the era of multiple telegraphy is opened, to be followed by the startling discoveries of the telephone and its mechanical analogue, the phonograph. If a telegraph engineer were asked to name the most important invention in telegraphic science during the last four years, the answer would undoubtedly refer to the telephone; and it is the accounts of this instrument that appear to be naturally sought when turning to the "Abstracts" to learn about progress in the applications of electricity. The discovery of the telephone follows in sequence the strange results obtained by Mr. Elisha Gray[1] when including a portion of the human body in the secondary circuit of an induction coil as a part of an apparatus for receiving musical sounds; and the valuable and striking invention of Professor Graham Bell[2] is found to be followed rapidly by descriptions of other modes of transmitting speech as invented, introduced, or improved by Trouvé,[3] Edison, and Breguet.[4] The invention of the telephone is singular in that the Bell instrument, which brings into play the principles of magneto-electricity, does not represent all the principles involved in apparatus by which speech can be transmitted.

---

*Vide* Minutes of Proceedings Inst. C.E., vol. l., p. 310; [2] vol. l., p. 311; vol. lii., p. 396; [4] vol. liii., p. 393.

In Edison's telephone two totally different and novel principles are involved, namely, the variation in current produced by variation in resistance caused by varying pressure or compression employed in the transmitting instrument, and the variation in friction caused by varying rate of electrolysis employed in the receiving instrument. But to M. Breguet's telephone the palm of novelty must be awarded; for in this instrument again is a wholly different and very little applied principle involved, that of the currents produced in mercurial surfaces in contact with acid electrolytes by movement or changes of surface, and the converse of movements or vibration produced by variation of current. Thus the telephone attains its end by either and all of four distinct scientific principles, three of which may be said to have been born into our sphere of knowledge as a result of competition with the invention of the first telephone for the transmission of speech. It may also be said of telegraphy that it stands first in the applied sciences, for the speed with which improvements are evolved when once the line of work is pointed out. Illustrating this is Dr. Siemens' Paper on telephony,[1] in which improved instruments are constructed on the consideration of the imperfections of the Bell telephone, and on acoustic principles as studied by Helmholtz.

But the effulgence attending the invention of the telephone, very like the brilliancy of the electric light, is somewhat calculated to lead to omission in the study of subjects of less *éclat*. Until the present time there are many difficulties in view with regard to the general use of the telephone except for short distances, and it does not now appear at all probable that this instrument will supersede the need of invention in fast speed and multiple telegraphs. Indeed, on long circuits, until speech shall have been made self-recording in a manner to be easily read by anyone from generally applicable apparatus, fast-speed automatic telegraphs will have the advantage in speed and accuracy of transmission. Between forty-five words and one hundred and eighty words per minute (the practical limits of present automatic writers), supposing these to be accurately transmitted by the telephone, ordinary handwriting must be replaced by shorthand, and from this transcription it is well known there is considerable risk of error. Progress in duplex signalling on land lines is well represented by Mr. Louis Schwendler's Paper[2] on the theory of duplex telegraphy, whose system is doing good service on the Indian Government lines, as well as in other countries. In

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liii., p. 395; [2] vol. xliv., p. 328.

multiple telegraphy there are described the "successive epoch" system of M. Meyer[1] and the use of tuning forks on Lacour's system,[2] both of which have not yet met with extended application; while illustrations of recently introduced quadruplex systems are unfortunately wanting, owing to the fact that they have not become developed sufficiently for general use on foreign lines, except in America. The application of the duplex system to submarine lines is represented by M. Ailhaud's method,[3] as employed on the Marseilles-Algiers cable, in which the "kick," arising from inequalities in the discharge from the actual and the artificial cable, is obviated in a manner somewhat similar to that adopted in Dr. Muirhead's method, by the interposition of a condenser in the instrumental circuit. The subject of increasing speed on submarine lines is sought to be aided by M. Lacoine,[4] who lays down the best proportion that the resistance of the coils of the instruments can bear to the resistance of the cable-conductor. On land lines this subject has been studied by M. du Moncel,[5] as well as by Mr. Brough,[6] who both give formulæ for maximum condition of electromagnets; whilst the troubles arising with such delicate instruments as the Hughes' Printer (an automatic arrangement for which is described by M. Renoir[7]), from the induction between two or more line wires where connected with earth cables, appear to be not very successfully obviated by the leakage resistances proposed by M. Lagarde,[8] as tried on the line between Paris and Florence, where the experimentalist assured himself that the mischief arose chiefly on the aerial lines.

As allied to progress in telegraphic construction may be considered the substitution, where possible, of underground for aerial lines, and the laying down of long subterranean lines, such as the seven-core cable connecting the city of Berlin with the town of Halle.[9] In Germany, however, there seems to exist a peculiar method of judging of the value of a cable by the smallness of its percentage of loss of current, the plan adopted for estimating this being described by Dr. Brix.[10]

Related to the construction of land lines is M. Bourseul's inquiry into the causes of destruction of wooden poles,[11] from "dry," "wet," and "black" rot, and the remedies; and the report upon the durability of the insulation of Brooks' insulators[12] as compared with

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxxix., p. 429; [2] vol. liii., p. 434; [3] vol. l., p. 308; [4] vol. xlix., p. 388; [5] vol. li., p. 395; [6] vol. lii., p. 397; [7] vol. xliv., p. 337; [8] vol. xlii., p. 386; [9] vol. lii., p. 395; [10] vol. l., p. 313; [11] vol. xli. p. 261; [12] vol. xliii., p. 433.

the porcelain insulator, the experiments in M. Gaugain's hands indicating equality, if not superiority, for the Brooks' insulator.

The laying and testing of submarine cables is represented by Dr. W. Siemens' Paper[1] on these subjects, which raised considerable discussion when translated and contributed to the Society of Telegraph Engineers, particularly with regard to the strains occurring on a cable during submersion.

Amongst the numerous applications of the electric current, as an aid in the arts and manufactures, is to be mentioned the coating of cast-iron cylinders with copper in a galvanoplastic bath, described by M. Schlumberger[2], for the purpose of printing upon calico and other stuffs, a process in which the difficulties have been unsurmounted for thirty years, but appear about to yield to a cheaper production of the electric current. As a means of reducing or precipitating copper from mother liquors too impure to yield merchantable sulphate, electricity has been proposed by Mr. Keith,[3] and it appears that the process could be conducted at a low cost. More nearly related to engineering pursuits is the application of electricity to blasting. Amongst the Papers on this subject is that by MM. Champion, Pellet, and Grenier,[4] relative to fuses and their construction; and Mr. Striedinger[5] describes the circuit closer for the simultaneous ignition of many mines as used at the great blast for the removal of the Hell-Gate rock,[6] where more than three thousand six hundred separate charges were simultaneously exploded.

At the present time electricity is asserting a claim upon public attention other than that presented by the telephone. According to the statements of some engineers of high standing, the days of gas-lighting are numbered; according to others electric lighting is a thousandfold too costly to come into common use. Probably these statements are the extremes between which the true mean is to be found, and containing some elements of both. As the Author has pointed out, in a Paper presented to the Institution,[7] the field for electric lighting is in the illumination of large open spaces, leaving to gas the lighting of small and of subdivided areas. It has also been pointed out, that with the means of subdividing the electric current, so that it can be made available for several small centres of light instead of one of abnormal power, the present advancement of gas lighting must cease, because there cannot be a doubt that

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlii., p. 380; [2] vol. xxxix., p. 425; [3] vol. lii., p. 404; [4] vol. xli., p. 267; [5] vol. l., p. 292; [6] vol. liii., p. 396; [7] vol. lii., p. 36.

the electric light can be produced more cheaply, is attended with less danger of fire, and is less detrimental to health, than gas. M. Tresca [1] shows that, with the Gramme machine, the cost of the electric light is, as far as regards the mere cost of coal to work the engines, only one-fifteenth of that of gas consumed at Paris prices, or one-hundredth part of the cost of oil; while M. Fontaine [2] points out that, under certain common conditions, the relative costs of electric and gas lighting are in the ratio of 1 to 14, and even using gas in an Otto and Langen gas-engine as a motor, the ratio is 1 to 3 in favour of electric lighting. These views are borne out by the evidence of M. Heilmann Ducommun,[3] M. Dieu,[4] and M. Delahaye;[5] and M. Jamin states that the Compagnie Lontin are willing to supply the electric light at a cost of 50 centimes per one hundred Carcel burners (nearly eight hundred candles), and that the Denayrouze-Jablochkoff system is maintained at a cost 30 per cent. less than the cost of gas. Much was expected from the introduction of the Jablochkoff "candle," [6] but neither in light effect nor economy has this invention superseded the Serrin lamp when used for a single light, although if it were to be applied in conjunction with the system of dividing the electric light, by the same inventor,[7] its advantages would, doubtless, be great. Much has been said about the divisibility of the electric light for the purposes of domestic illumination. Such a well-regulated system as the present gas system can be scarcely expected to spring full-grown into existence, and it must be remembered that the present gas system had its period of development. There is, however, a method which seems to have been overlooked, by which, when electric lights of sufficient power are employed to illuminate streets, houses might also be lighted, and that is by admitting the rays of the artificial source as the sun's rays are now admitted, by the window. The present objection would be, that the electric light is not sufficiently diffused, a difficulty that might easily be overcome, if the out-door use were general. There is, however, a field in which the advantages to be derived from the use of electric light machines are incontestable, and that is on board ship, whether in navigating the open seas or in entering or leaving ports and roadsteads. That these advantages, as well as those arising from the use of the light as an aid in the detection of torpedo vessels, are appreciated is fully evinced by

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliv., p. 338; [2] vol. xliv., p. 339; [3] vol. xlvii., p. 418; [4] vol. xlix., p. 396; [5] vol. lii., p. 405; [6] vol. xlvii., p. 417; [7] vol. l., p. 312; vol. lii., p. 405.

the applications of the light on board vessels of the French navy.[1]

Improvements in sources of the electric current are chiefly to be found in developments of magneto- and of dynamo-magneto-electric machines, with two notable exceptions, the Leclanché battery and the Clamond thermo-pile. M. Leclanché[2] not only tells what the improvements in his justly-celebrated battery are, but also gives interesting particulars as to how the cells are manufactured, and what the effect is of slightly increasing the chemical action—a result that might probably be worked out as a proof of the chemical theory of voltaic action. By substituting for galena an alloy of zinc and antimony, retaining iron for the electro-positive element, M. Clamond[3] has constructed a thermo-pile capable of depositing 20 grammes of copper per hour with a consumption of 170 litres (5·95 cubic feet) of gas as shown by Count du Moncel.

The sources of electricity, as derivable from the expenditure of mechanical power, best known in the English market, are the Gramme and the Siemens machines. These machines have received descriptions[4] at considerable length. From M. Tresca there is a full report of the lighting power of the Gramme machine before referred to, and Dr. E. Zetzsche[5] describes the machine invented or perfected by Herr von Hefner Alteneck, but better known as the Siemens machine. The Lontin machine,[6] which differs from the Gramme and the Siemens machines as being a radial machine—that is, a machine with independent magnets in the revolving portion, set radially—has been employed for obtaining a series of light centres from one common machine and motor. The result appears to be increased consumption of motive power expended, which may however be reduced in improved forms of this machine.

The principles relating to the work done and power expended in all magneto-electric and electro-magnetic engines have been but little developed, and this fact renders the labours of M. Mascart,[7] who has both mathematically and experimentally investigated this relation, doubly valuable, as affording to the electrical engineer a scheme for his calculation based on the most reliable data.

In the yet unapplied principles that have been deemed of sufficiently great and general interest to obtain a place in the

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlvi., p. 372; [2] vol. xlvii., p. 412; [3] vol. xli., p. 338; [4] vol. xlv., p. 338; [5] vol. xliii., p. 435; [6] vol. li., p. 397; [7] vol. l., p. 310.

Abstracts, the most noticeable is the confirmation of the theory of the relation existing between light and electricity as laid down by Professor Clerk Maxwell, and supported by the independent experimental researches of Boltzmann [1] and of Silow [2] for gases and for fluids. Professor Maxwell, it may be said, prophesied that it would be found that the square root of the dielectric constant equalled the index of refraction; and this has been declared the case by these two experimentalists and by others. The relation between the motion of the conductor and the resistance it opposes to the passage of the current, has received investigation from the hands of Herr Edlund,[3] who found that when the electric current and a conducting current of water flowed in the same direction, the resistance was diminished, whilst it was increased when the currents flowed in opposite directions. From Professor Clausius [4] the electrician obtains an enunciation of a law of reciprocity in reference to mutual induction between two electrical conducting bodies; and Professor Mascart [5] has given some startling facts to the effect that evaporation under the electric influence is greatly increased, it being sometimes double in vessels submitted to this influence; between the influence of positive and negative electricity, there appears to be no difference in this effect.

Generally, it may be stated that the most important applications of electrical science are at the present time in a condition of active development, which may at any moment produce results that will leave the advanced post of present knowledge far behind.

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlii., p. 374; [2] vol. xliv., p. 336; [3] vol. xliii., p. 432; [4] vol. li., p. 397; [5] vol. liii., p. 390.

# MEMOIRS OF DECEASED MEMBERS.

MR. WILLIAM BAKER was the son of an officer in the service of the East India Company, and was born on the 19th of May, 1817; he was educated partly at a private school and partly under a private tutor. Having decided to adopt the profession of a Civil Engineer, he was, in 1834, articled for five years to the late Mr. George W. Buck (the eminent engineer, well known for his able mathematical treatise on skew bridges), who acted on behalf of the late Mr. Robert Stephenson, in charge of the construction of a portion of the London and Birmingham railway between London and Tring. Upon the opening of that section of the line, in October 1837, Mr. Baker accompanied Mr. Buck to Manchester, and under his supervision took charge, at the age of twenty-one, of the construction of a portion of the Manchester and Birmingham railway, upon which he was employed until 1842. Subsequently he became Engineer to the Manchester, South Junction, and Altrincham railway, and at the same time was engaged on the works of the Shrewsbury and Birmingham and Shropshire Union railways, which were opened in the year 1849, after which Mr. Baker was appointed Engineer to the Stour Valley railway between Birmingham and Wolverhampton. Whilst in charge of that line he was appointed, in 1852, by the London and North Western Railway Company, Engineer upon the southern division of their system, in the place of the late Mr. R. B. Dockray, M. Inst. C.E., in which capacity he remained up to the death of Mr. Robert Stephenson, in October 1859. The North Western Railway Company, at this time contemplating large extensions of their system, and finding that an Engineer of recognised ability, possessing an intimate knowledge of their undertaking, and whose time should be wholly devoted to their interests, was of the utmost importance, selected Mr. Baker to fill the office of Chief Engineer. The amalgamation of the London and Birmingham, Manchester and Birmingham, and Grand Junction railways took place in 1846. It will thus be seen that Mr. Baker's previous experience highly qualified him for the position to which he was raised, as, from the first period of entering upon his career in 1834, he had the opportunity of observing the growth of the London and North Western Company, and that he had been practically employed upon a large portion of it.

Within the limits of this memoir it would be impossible to describe the variety and character of the numerous engineering works carried out under Mr. Baker's immediate and able supervision; but all who are acquainted with the line with which he was so long and closely connected, will admit that the great lattice-girder bridge carrying the railway over the River Mersey at Runcorn, is a lasting monument to his genius and indomitable perseverance in overcoming difficulties of no ordinary character. It is also worthy of record that he wholly constructed, or remodelled and extended, the great central stations of the North Western Company in London, Liverpool, and Manchester, as well as the stations in Birmingham, Preston, Bolton, Crewe, Warrington, Stafford, and other places, besides widening the main lines for a length of 100 miles, and constructing a new harbour at Holyhead. In short, it may perhaps be asserted that scarcely any Engineer ever carried out a greater extent of railway works, or controlled the expenditure of a larger sum of money, than Mr. Baker. In addition to the eminence to which he attained as a practical Engineer, he was for many years recognised as a most valuable witness in support of the numerous schemes proposed by the company in Parliament, and his evidence on all occasions was received with due regard to the extensive knowledge upon which it was based. So great was the confidence of the directors in Mr. Baker's high character and unswerving integrity, that for a period of nearly twenty years he was constituted their sole arbitrator in all contract works, and in the many cases in which he exercised that function his decisions were held as just and equitable. In addition to holding the office of Chief Engineer to the London and North Western Railway Company, he acted in a consultative capacity as Engineer to the following railways, in which that company is largely interested, namely, the West London Extension railway, connecting the lines north and south of the Thames on the west side of London, which he constructed in the years 1859-63; also to the North London railway, the City branch of which, including the new station at Broad Street, was carried out under his superintendence in 1863-66. He was also associated, as Engineer, with all railways undertaken jointly with the North Western Company, and was Engineer in charge of the construction of the Dundalk, Newry, and Greenore railways in Ireland, and the North Wall Extension railway and station in Dublin. He was likewise one of the consulting Engineers for the International Exhibition of 1862.

Mr. Baker possessed a singularly retentive memory, was methodical and exact in all things, fearless in the expression of his opinion,

matured in the knowledge of men and business, generous in the exercise of the large influence he possessed, and cordial and considerate to his large staff, in whom he placed the greatest confidence, and who held him in the highest esteem. His high reputation, honourable character, and gentlemanly bearing will long be held in remembrance, not only by those members of the profession to which he was so ardently attached, but by everyone who enjoyed his acquaintance. It was observed by those immediately around him that early in the year 1877 his health began to show signs of yielding; but his active mind and vigorous habits sustained him through the parliamentary campaign of 1878, after which he was compelled to give way to the entreaties of his advisers and take rest. Gradually, however, his strength failed, and after being confined to his house for nearly three months, he died on the 20th of December, 1878, of Bright's disease. He was elected a Member of the Institution of Engineers on the 7th of March, 1848, and served as a Member of Council for the last year of his life, having been re-elected to that office three days before his death.

---

SIR RICHARD GRIFFITH, BART.,[1] was born in Hume Street, Dublin, on the 20th of September, 1784, and in 1797 obtained a commission as lieutenant in the Royal Irish Artillery, which he held for only one year, the corps being disbanded by the Act of Union. Turning his attention to civil engineering, he applied himself to the study of mining in Cornwall, and in various districts of England, Wales, and Scotland, completing his general education at Edinburgh, and he was elected a Fellow of the Royal Society in that city at the early age of twenty-three. Immediately afterwards he returned to Ireland and entered upon his professional career. He then commenced, in connection with the Royal Dublin Society, the publication of "A Geological and Mining Examination of the Leinster Coal District," and in 1814 completed the work. In 1809 he received his first public appointment as engineer by the Commissioners selected to inquire into the practicability of draining and improving the bogs of Ireland, and at the same time was selected to fill the office of Inspector-General of His Majesty's Royal Mines in Ireland. After the Irish famine in 1822, the Viceroy, Lord Wellesley, appointed Mr. Griffith, as engineer, to improve and construct roads in the counties of Cork,

[1] This memoir has been compiled chiefly from the "Times" newspaper.

Kerry, and Limerick. The result of his labours was that in the year 1830, 250 miles of new roads had been made, and places which had been before inaccessible were brought within easy reach of civilization and authority. While he was thus engaged, the first edition of the geological map of Ireland was published, and, before the institution of the Ordnance Survey, he was appointed General Boundary Surveyor. In 1828 the general scheme, which was however initiated by other officers, was organized, and he was appointed Commissioner for the general survey and valuation of rateable property. He was subsequently employed by the Government on various public undertakings, and was, in fact, referred to as an authority in engineering and other works for the improvement of the country. One of the most useful was the diversion of the River Liffey in Dublin. He was appointed one of the Commissioners for the improvement of the Shannon, and to various other public positions, the most important of which was the Board of Works, of which he was nominated deputy-chairman in 1846, after the memorable famine. In 1854, on the outbreak of the Russian war, he became chairman in place of Sir Henry D. Jones, who was ordered to the Crimea. In this office he had charge of the Land Improvement and Drainage Works. He was also the chief ædile as regards the public buildings erected by the Government, and in the construction of its national gallery and museum of natural history he showed, if not classical taste, at least a practical knowledge and foresight in working out the design with a view to utility. In 1855, on the completion of his geological map of Ireland, he was presented by the late Professor Forbes, President of the Geological Society of London, with the Wollaston Medal, and in 1858 he was created a baronet in recognition of his public service.

Sir Richard Griffith was elected a Member of the Institution on the 11th of June, 1839, and he died on the 22nd of September, 1878.

---

MR. JAMES McNAIR HARKNESS received his professional education under his brother, and commenced practice as an assistant engineer on the North Devon railway and Docks. Subsequently he was employed as resident Engineer, under the late Captain Vetch, R.E., on the drainage of Windsor Castle, and for supplying Frogmore Lakes with water. He next planned and carried out, under Mr. John Roe, the drainage works of the town of Windsor, as Engineer to the Local Board of Health, and was for three years

engaged under Messrs. Locke and Errington, in making parliamentary and permanent surveys. For the last twenty-three years of his life he was in practice as an engineer on his own account, during which time he was occasionally employed by the Office of Woods and Forests in planning and executing drainage works, and by the Admiralty in inspecting and reporting upon Government works. He drained the Clewer Estate, superintended the construction of the Kew and Barnes curves of the London and South-Western railway for Mr. James Taylor, the contractor, was the Engineer of the Kingsbridge railway, and prepared the plan, and laid out the line of the Windsor and Ascot, the Downham, Stoke Ferry and Brandon, and other railways. Mr. Harkness was elected an Associate of the Institution on the 4th of March, 1862, and was transferred to the class of Member on the 23rd of May, 1876. He died on the 25th of June, 1878.

---

Mr. JULIAN HORN TOLMÉ was the youngest son of the late Mr. Charles David Tolmé, merchant, for many years Her Britannic Majesty's Consul at Havana, in Cuba, in which city Mr. Tolmé was born, on the 28th of January, 1836, and where he received the rudiments of his education. On his father's return to England, about the year 1851, he was entered as a student at King's College, London, where he took a distinguished position, especially in geology and mineralogy. After attending the Civil Engineering classes of the College, he was, in 1855, articled for five years to Messrs. Locke and Errington. It was chiefly under Mr. Errington, at that time Engineer-in-Chief to the London and South Western Railway Company, that Mr. Tolmé was employed. He was deputed to superintend various important works then in course of construction, being successively placed in charge of the Salisbury station, and works in connection therewith; the Barnes and Kew curves; and the branch to Kingston. He also assisted to prepare Parliamentary plans for the Company, as well as for the London and North Western Railway Company in Yorkshire and in Derbyshire.

Upon the death of Mr. Errington in 1862, following that of Mr. Locke in 1860, Mr. Tolmé and Mr. W. R. Galbraith, M. Inst. C.E., who had been two of the principal Assistant Engineers of the late firm, and the former of whom had been appointed by Mr. Errington as one of his executors, entered into partnership for the purpose of continuing the practice. Mr. Galbraith was appointed

Chief Engineer to the London and South Western Company, and Mr. Tolmé carried on other works of the late firm. That partnership expired by efflux of time in 1869, after which Mr. Galbraith and Mr. Tolmé, though continuing to occupy the same offices, conducted separately the various works entrusted to them.

Amongst many minor works, Mr. Tolmé acted as Engineer to the following: the Thames Valley railway, the Alton Alresford and Winchester (now known as the Mid Hants) railway, the Garstang and Knot End railway, the completion of the Shrewsbury and North Wales railway (commenced under Mr. Ashdown), the Newport Pagnell Railway, the Harborne railway, the Wigtonshire railway, the bridge carrying the new road over the river Thames at Wandsworth, the Gellivara railway and canals in Sweden, and the completion of the Tunisian railways. In conjunction with Mr. A. S. Hamand, M. Inst. C.E., he acted as Engineer for the Birmingham District tramways, the Halesowen railway, and the Whitby, Redcar, and Middlesboro' Union railway; whilst with Mr. F. S. Gilbert he was associated in the construction of the extension to Hammersmith of the Metropolitan District railway. He was also consulting Engineer to the Yarmouth and North Norfolk Railway Company; consulting Engineer from 1866 to 1870 to the London Financial Association; and one of the last works with which he was connected was a railway from Brighton over the Downs to the Devil's Dyke.

He was much interested in the volunteer movement, and at its beginning took a leading part in the formation of the 3rd Middlesex Artillery, which was originally composed, in great measure, of men in the service of the London and South Western Company. Shortly before his death, after fifteen years' service, he retired from the Reserve Forces with the rank of Lieutenant-Colonel.

The immediate cause of his death was acute rheumatism, from which he had suffered for a month previously. He died in the forty-third year of his age, at his residence, Lindfield, Sussex, on the 25th of December, 1878, and was buried in the family vault at Highgate Cemetery, London. A man of extensive knowledge and experience, great amiability and social powers, and with a singularly winning manner, accompanied by a handsome presence, Mr. Tolmé was known to a large circle of friends and acquaintance, who will deplore his early loss.

Mr. Tolmé was elected an Associate of the Institution on the 7th of May, 1861, and was transferred to the class of Member on the 13th of March, 1866.

MR. WILLIAM THOROLD was born on the 9th of October, 1798, at Northwold, on the confines of the Bedford Level in Norfolk. He was the son of a farmer, and in 1812 commenced life by assisting his parents. Afterwards he took a farm at Melton, Norfolk, and until 1827 continued the business in his own person, and up to 1831 by means of bailiffs. While attending the opening of the Eau Brink Cut, in 1821, he determined to become a Civil Engineer; and, acting on advice received through a friend from Mr. Telford, he entered on the trade of a millwright and engineer at Norwich, in 1828, making mills of all kinds, steam-engines for draining, grinding corn, and propelling boats; constructing sluices, roads, catch-water drains; and superintending rural architecture, and building Union workhouses. While so employed he discovered that the circulation of water in a steam-boiler was as essential as the circulation of blood in the human body, and sent a Paper on the subject to the Institution of Civil Engineers, as also a Paper "On Turnpike Roads." In 1826 he published a pamphlet "On the Means of Making Norwich a Port," by a canal from Reedham to a point near South Town, and he was employed by Sir W. (then Mr.) Cubitt to make some of the works required for the locks at Mutford Bridge, now the property of the Great Eastern Railway Company. In 1829 he published another pamphlet, "On the State of the Law relative to Patents for Inventions." Mr. Thorold was proud of having been complimented on his knowledge of road-making by Thomas Telford. For many years he was Surveyor to the Norwich, Swaffham, and Mattishall, the Norwich and Scole, the Norwich and New Backenham, the Norwich and North Wolshaw, and the Norwich and East Dereham turnpike roads. He also constructed a new direct road between Norwich and Great Yarmouth. His establishment was destroyed by fire early in 1840, but he soon got it into order again, and constructed a large quantity of contractors' plant, railway switches, drainage engines, and a stationary engine for the Norfolk railway. The following extract from a list of works executed by him, which was submitted to the Commissioners of the River Witham Drainage, when a candidate for the post of Surveyor to the Board in 1863, may be cited as an example of his general practice. "New water corn mill and water sluice on a dry turnip field at Heacham, near Hunstanton, and in sight of Boston Stump, for H. Styleman, Esq., and, after so built, bringing the river from an old mill-head (above the new mill) within an embanked pool covered with a pie-crust puddle over the turnip ground; then cutting a tail drain or leat for the new mill to the river below another old mill, and

lowering and underpinning a road-bridge to obtain 13 feet fall in all." Mr. Thorold was awarded two silver medals in 1827 by the Society of Arts[1]; one for a machine for slicing turnips, the other for the improvement of the reel of Captain Manby's life-saving apparatus. In 1847 and 1848 he was engaged principally in the manufacture of turntables which came into use on the Manchester, Sheffield, and Lincolnshire, the Great Eastern, and the Midland railways, and at Portland breakwater, and on a railway in Norway. But railway work slackening in 1849 and 1850, and his eldest son showing no decided tendency to mechanical pursuits, he closed his establishment at Norwich early in 1851. Henceforward he retired to a great extent from active business, but practised as a consulting engineer, and retained his road surveying appointments.

His connection with the Institution of Civil Engineers dates so far back as the 30th of January, 1827, when he was elected an Associate; he was transferred to the class of Members on the 8th of June, 1830. In May 1845, he contributed "An account of the failure of the Suspension Bridge of Great Yarmouth,"[2] which had occurred a few days previously; and for some years afterwards he occasionally joined in the discussions on the Papers. Mr. Thorold was a man of great physical strength. Although for the last few years of his life he was almost blind, he took great interest in the reports of the Proceedings of the Institution, which were read to him, and he kept up as far as he could, almost to the latest day of his life, with the principal engineering questions of the day. He died at Thorpe Hamlet, Norwich, on the 17th of December, 1878, in his 81st year.

---

MR. JOHN THOMAS WOODHOUSE, the eldest son of Mr. Jonathan Woodhouse, a well-known mining engineer of his time, was born at Overseal, Leicestershire, on the 19th of May, 1809. He was left an orphan at an early age, and was brought up by his guardian, Mr. Edward Mammatt (agent to Lord Moira, afterwards first Marquis of Hastings, and to George, second Marquis of Hastings), and was educated first at Ashby Grammar School, and afterwards at Repton School. After leaving school he was articled to Mr. John Twigg, of Chesterfield, who then had a considerable practice as a mining engineer in the Derbyshire and adjacent coalfields.

---

[1] *Vide* Transactions Inst. C.E., vol. xlv., pp. 47, 75.
[2] *Vide* Minutes of Proceedings Inst. C.E., vol. iv., p. 291.

About the year 1834 Mr. Woodhouse commenced to practise as a civil and mining engineer, at Ashby-de-la-Zouch. On the death of Mr. Mammatt, in 1835, he became mining engineer to the Marquis of Hastings, at the Moira and Gresley collieries, having already given proof of that great ability which, in after life, was developed in a remarkable degree. Meanwhile, in addition to holding this and other important appointments, he entered into partnership with Mr. Twigg, which continued until the death of the latter, in 1839.

Mr. Woodhouse, being endowed with great talent and skill in the performance of professional work, having indomitable perseverance and remarkable energy, gradually raised himself to a prominent place amongst the engineers of the time. Besides holding the appointment already noticed, he was the responsible mining engineer of the extensive collieries at Moira, Oakthorpe, Measham, Gresley, Baddesley, Wyken, Shipley, Hallam, Workington, the Oaks, Wharncliffe, Silkstone, Woolley, and a large number of other extensive undertakings in different coal-fields of the kingdom. He will also be remembered as the first mining engineer who solved the problem of the continuity of the Coal Measures under the Permian strata in the Midland coal-fields, by putting down a bore-hole to a considerable depth at Lady Lee, near Worksop, in the year 1835. He thus practically settled, to the satisfaction of the Duke of Newcastle, the question which Sir Roderick Murchison and other geologists had theoretically determined. He opened and developed the large collieries at Cinder Hill, in the neighbourhood of Nottingham, where several shafts were sunk through the superincumbent Magnesian Limestone to the Coal Measures. It was principally owing to his professional advice and skill that the extensive collieries at Staveley, belonging to the late Mr. Richard Barrow, were so successfully opened and developed. Among many difficult works which he brought to a successful issue may be named the winning of the Bettisfield Collieries, near Bagillt, in the North Wales coal-field. After encountering great, and almost insuperable obstacles, he succeeded in sinking the shafts through quicksands on the banks of the Dee, and thus opening a large coal-field previously unavailable. In addition to the important engagements in connection with these undertakings, he had a large consulting and general practice, and acted as mining engineer to the Duchy of Lancaster, the Duke of Portland, the Duke of Newcastle, the Duke of Devonshire, the Duke of Leeds, the Marquis of Anglesea, and many other large coal owners and lessors. He was also consulting engineer on mining matters to

the Midland Railway Company, and to several other similar companies.

In 1856 Mr. Woodhouse entered into partnership with the late Mr. Parkin Jeffcock, a former pupil of his, and a member of the Institution of Civil Engineers; and this partnership continued until the death of Mr. Jeffcock, at the explosion at the Oaks collieries, in December 1866, when his life was lost in heroically endeavouring to save the lives of others. In 1866 Mr. Woodhouse was appointed one of the members of the Royal Commission to inquire into the coal supply of Great Britain, and was thus employed as a Royal Commissioner until 1871, when the Commission completed their valuable labours. On account of his large professional experience and sound judgment, he frequently acted in the capacity of sole arbitrator, or umpire, in important colliery and other disputes, and in many cases large sums of money and difficult points of engineering practice were involved. In this capacity he generally settled the matters before him in a manner satisfactory to the parties concerned. In 1872 he was appointed one of the arbitrators under the South Staffordshire Drainage Commission, having Mr. Hawksley (Past-President Inst. C.E.), and Mr. Dowdswell, Q.C., as his colleagues; and he performed the duties of arbitrator to the satisfaction of the coal and iron masters of the South Staffordshire district within the jurisdiction of the Commission.

During his professional career Mr. Woodhouse had a considerable number of articled pupils, in whose welfare and preparation for professional life he took the greatest interest, and did everything in his power to forward their aims in life. Mr. Woodhouse was of a genial and hospitable disposition. He had a large circle of friends; and, as he was a keen and ardent sportsman, he especially delighted in having the company of those of congenial tastes with him at his shooting quarters in Scotland, to which he resorted annually for more than thirty-five years. He was warm in his attachments, abiding in his friendships, and generous almost to a fault; he possessed a high sense of honour and justice, and was always ready to promote any charitable or benevolent work by his money and influence; and his death leaves a void which will not easily be filled up.

He was elected a Member of the Institution of Civil Engineers on the 18th of May, 1852, and occasionally took part in the discussions at the meetings, and was always anxious to promote the interests of the Institution in every way. He was also a Fellow of the Geological Society, Vice-President of the North of England

Institute of Mining Engineers, Vice-President of the Derbyshire Institute of Civil and Mining Engineers, Member of the Institution of Mechanical Engineers, and was one of the original founders, and first President, of the South Yorkshire Viewers' Association. In 1873 he was appointed by the Home Office one of the three Examiners of the Midland District for examining candidates for certificates of competency as mining managers.

He died very suddenly from heart disease, at Scarborough, on the 27th of September, 1878. Although he had been for some months previously in failing health, no immediate change for the worse had been noticed, and on the day of his death he had taken his accustomed exercise, and appeared in no worse health and spirits; but at half-past eight o'clock in the evening, whilst apparently asleep, he peacefully passed away, without any sign of pain or suffering. He was buried on the 5th of October, in the churchyard at Overseal, where other members of his family lie.

---

MR. HENRY WILLIAM FERDINAND BOLCKOW, M.P., was born at Sülten, in the Grand Duchy of Mecklenburg, on the 8th of December, 1806, and died at Ramsgate on the 18th of June, 1878. He was elected an Associate of the Institution of Civil Engineers on the 14th of April, 1863.

Mr. Bolckow, whose name is inseparably connected with the great iron trade of Cleveland, came to England in 1827, and, in partnership with Mr. C. Allhusen, was in business at Newcastle until 1839, when he associated himself with the late Mr. John Vaughan, then managing the Walker Iron Works, and with him removed to Middlesbrough. At this time there was, practically, no manufacture of pig iron in or very near the Cleveland district, and Messrs. Bolckow and Vaughan made wrought iron in a small way from Scotch pig iron and scrap. The adventure was not very successful; and in 1846 the firm acquired collieries in South Durham, and established, at Witton Park, blast furnaces for the manufacture of pig iron from the clay ironstone of the coal measures. A short experience showed that the supply obtainable was wholly inadequate; and Messrs. Bolckow and Vaughan commenced to use the ironstone of Cleveland, which, though it was known to exist at various points, and had frequently been tried experimentally, was thought to be of no practical value. After much patient search the main bed of Cleveland ironstone, now so largely worked, was, chiefly through the exertions of Mr. Vaughan

and of Mr. Marley, M. Inst. C.E., traced to the Eston Hills, and blast-furnaces were erected at Middlesbrough to work it. By this time railway communication with the adjacent coal fields had been established, and the improved river Tees gave a good and convenient outlet for the pig iron produced. Henceforward the path of Mr. Bolckow and his partner, which hitherto had been difficult and discouraging, led rapidly to prosperity; and in 1864, when they disposed of their business to a limited liability company, the works handed over were, for extent and efficiency, among the first in existence. Mr. Bolckow was chairman of the new company, and was ever foremost in advocating improvements and progress. It is in a great measure due to him that the large steel works at Eston were established.

In his locality, as well as in the iron trade, Mr. Bolckow won for himself the highest respect and confidence. He had great enterprise and sagacity, and in everything connected with the well-being of those in his employ, and the district, he was very prominent and popular. He was the first Mayor of Middlesbrough, and gave to the borough a public park of large extent, which was formally opened by his Royal Highness the Duke of Connaught, K.G. (then Prince Arthur), on behalf of the Queen. When Middlesbrough became a Parliamentary borough, Mr. Bolckow was unanimously elected its first Member, and he continued in that position while he lived. As a patron of art he was well known, and left behind him a collection of pictures such as has rarely been brought together in a single lifetime. On the 22nd of June, 1878, in the churchyard at Marton, close to the fine Hall in which he lived, he was buried by the side of his partner, Mr. Vaughan, with whom so much of his active honourable life had been spent; and it is scarcely an exaggeration to say that his funeral was attended by the whole population of the neighbourhood. It is hardly to be expected that Cleveland will soon again look upon the like of the two men by whom its enormous iron trade and general prosperity were founded.

---

MR. JOHN BOYD was born at Hexham on the 16th of May, 1810. When about eighteen years of age he commenced his career, under the firm of John Abbot and Co., of Newcastle-on-Tyne, whose intimate friendship he retained during the lives of both father and son. In 1848 he came to London as financial agent to Messrs. Bolckow and Vaughan, of Middlesbrough-on-Tees, with whom, in their works and collieries, he was connected during

many years, and took the whole of their railway orders and engagements. His probity and integrity of purpose were such, and so generally known by all with whom he was connected, that the firm of Abbot and Co. offered to accept him as a partner some time after he came to London. Mr. Boyd occasionally took part in the discussions at the Institution of Civil Engineers, but failing health for some years prevented his attendance at the meetings. In politics he was a Liberal, and in the borough of Chelsea, where he resided, his personal interest and friendship were given to Sir Charles W. Dilke, Bart., M.P. His ideas were ever of progress and the common weal, and he was especially well able to judge of the question of Capital *versus* Labour. Mr. Boyd was elected an Associate of the Institution on the 7th of December, 1852. He died at Eastbourne on the 17th of October, 1878.

---

Mr. CHARLES CURREY, the only son of the late Rev. Charles Currey, Vicar of Heath, Derbyshire, was born at Borden, Kent, on the 9th of June, 1833. He was educated at Marlborough College, and, on the death of his father in 1852, entered the service of the Great Northern Railway Company, then under the management of the late Mr. Seymour Clarke, Assoc. Inst. C.E. This service afforded an excellent practical training, and Mr. Currey, after passing through various grades, by his great ability and industry became superintendent of the line, and it was the general opinion of those best able to judge, that had he remained in this country, a distinguished position among railway managers here, awaited him. The Great Northern railway has furnished many of the most competent officers for the traffic service and general management of Indian railways, and, at the beginning of 1865, Mr. Currey applied for the Indian agency (then vacant) of the Great Indian Peninsula Railway Company. He was unsuccessful in securing this post, the nomination of the Board of Directors for the appointment falling to the late Admiral, then Captain, Sherard Osborn, R.N. Mr. Currey's aptitude for a position of this nature was, however, recognised by the Government Director for Indian railways, Mr. Juland Danvers, who shortly afterwards recommended him to the Board of Directors of the Bombay, Baroda, and Central India Railway Company, as a suitable successor to their agent, then about to retire. Communications followed, which resulted in the Indian agency of that company being accepted by Mr. Currey, who proceeded to Bombay

in April 1865. The Bombay, Baroda, and Central India railway had then been for only a short time opened to Bombay, the extension of the line from Surat southward to Bombay having been carried out after the section from Surat northward to Baroda and Ahmedabad was built.

In India Mr. Currey's intelligence and power of application found plenty of opportunities, while his ability and capacity for good service were fully and constantly recognised, both by the Board of Directors whom he represented, and by the authorities of the Bombay Government with whom he was in continuous communication on behalf of the company. His cautious tact, sound judgment, and practical character led to his nomination by the Bombay Government as member of a Government Commission, appointed in 1872, to report on the subject of the connection of the port of Carwar with the interior, by railway passing over the Ghauts; and shortly afterwards, when, in 1873, the municipal constitution of Bombay was considerably changed, and the element of election by popular vote was introduced into the assemblies charged with the local government of the city, Mr. Currey received the compliment of being appointed by Government the first chairman of the then newly-created Town Council. In this position he did valuable service, and greatly facilitated the regular and practical working of a new organisation intended to give the ratepayers and householders in the mixed community of Bombay increased control over their local municipal affairs. Mr. Currey held this position until early in 1875, when in failing health he returned to England on furlough. While in England on this occasion he offered himself, with the full consent of the directors of his own company, as a candidate for the Secretaryship, then vacant, of the North Eastern Railway Company, and was one of four candidates selected as the best qualified out of a large number, from whom the final nomination was made. But this nomination did not fall on Mr. Currey, and he consequently went back to India. His health, however, gradually gave way, and therefore when, on the death of Mr. J. A. Baynes, for many years secretary of the Bombay, Baroda, and Central India Railway Company in London, the Directors offered the post to Mr. Currey, he gladly accepted it, and left the tropics. He had only held this last appointment for about two years and a half, when death removed him, on the 11th of September, 1878. Mr. Currey has left many friends, who appreciated his worth. On hearing of his death, the Bombay Government issued a Gazette Extraordinary, in which they acknowledged the good service he had rendered

to his company, to the city of Bombay, and to Government, and, in doing so, they only expressed the feeling of all who knew him.

Mr. Currey was a Justice of the Peace and a Fellow of the University of Bombay. He was elected an Associate of the Institution on the 7th of December, 1875.

---

Mr. THOMAS BARNABAS DAFT was born at Birmingham, in 1816. He was early apprenticed to a clever mechanic named Egginton, who, among other occupations, was in the habit of making models for engineers. Here Daft learned his business so promptly that at the age of fifteen he constructed a small working steam-engine entirely with his own hands. A year or two afterwards he commenced business as a model and instrument maker on his own account; and at the age of nineteen, having saved some money, he joined his father in a larger business as iron founders, and manufacturers of metallic hot houses, erecting large structures of the kind in various parts of the kingdom.

In 1839 he resumed the manufacture of philosophical apparatus, and soon afterwards he was consulted by the late Mr. Brockedon on the manufacture and use of india-rubber, which had been recently much improved by the process of "vulcanizing." Mr. Daft at once saw the great capabilities of the improved material, and he devoted himself with energy to its applications, which occupied him more or less for the whole of his subsequent life. One of the earliest uses he put it to was to form the "elastic bands" which are now in such every-day use. He proposed the plan of making a series of them in concentric circles, and designed at once the machine which has ever since been exclusively used for cutting out the whole series at one blow. His inventions and improvements in regard to india-rubber attracted much attention, and he was soon afterwards engaged by the firm of Charles Macintosh & Co. to manage their extensive india-rubber works at Manchester—a post he filled with great advantage to them and credit to himself for many years.

In 1856 he joined, as managing partner, the "Irish Engineering Company," who had a large establishment in Dublin; but the business was not prosperous, and he lost by it a considerable property. At later periods he was connected with india-rubber manufacturing works at Tottenham and at Northampton.

Mr. Daft was an ingenious and prolific inventor, twenty-eight patents being taken out between 1839 and 1877 in his name. Many of these had to do with the subject he had made peculiarly

his own, among them being the manufacture of elastic webbing, the well-known cellular india-rubber mats, and the application of the same substance to the coating of metals. But several of his inventions were more pretentious: he contrived a new mode of sheathing ships; he had an idea that a peculiar construction of large raft, worked by steam power, would be advantageous for marine purposes; he wished to revolutionize railway construction by substituting sledge motion for the rolling wheels and axles; and he had an ingenious plan for laying down a tunnel across the Straits of Dover. On these schemes he unfortunately wasted much time and money without any return. But the list included many other inventions of minor kinds, which were both useful and profitable, several being taken up by manufacturers and worked extensively without connection with his name. He also furnished the Ordnance Department with plans for conveying heavy guns across bogs, and for molten iron shell.

He was elected an Associate of this Institution in February, 1860, and he died in London on the 4th of December, 1878.

---

MR. CHARLES WILSON FABER was born in 1813, and educated at Winchester, and at Christ Church, Oxford. He was called to the bar of the Inner Temple about the year 1837, but principally devoted his energies to railway matters. He was largely interested and took an active part in the affairs of the Great Northern Railway Company, of which he became a Director in 1854. He was for many years Chairman of the Traffic Committee and a Member of the Way and Works Committee of that Company. In the latter capacity he took an enlightened and practical interest in all mechanical improvements. On the introduction of Bessemer steel Mr. Faber aided materially in an inquiry instituted to examine into the probable economy and security to be attained by its use for rails, which resulted in its immediate adoption by the Great Northern Company at all points where the heaviest weight of traffic passed over the railway, and its gradual extension over the whole system. He showed much interest in the welfare of the servants, subscribed liberally to their funds, and presided over the Reading Society's meetings.

Mr. Faber was a Deputy Lieutenant and a Magistrate for Herts, and a Magistrate for the West Riding of Yorkshire. He was elected an Associate of the Institution on the 3rd of December, 1867. He died at San Remo on the 1st of April, 1878.

---

MR. HENRY POOLEY was born in West Derby, a suburb of Liverpool, on the 4th of January, 1803. He was the third son of Mr. Henry Pooley, an ironfounder of some note in Liverpool, and one who sought to excel in all that he undertook. But as his favourite maxim was "If a thing is worth doing at all, it is worth doing well," profit was often lost sight of in the desire to attain this object. The subject of this notice was apprenticed to his father. Being trained in a thoroughly practical school, much under his father's eye, he soon became expert in the use of tools. His evenings, and almost all spare hours, were devoted to scientific studies; he also acquired a knowledge of drawing at the classes formed by the father of the late Mr. Spence, sculptor, of Rome. His industry and talents enabled him, on the completion of his seven years' apprenticeship, to take an active part in the management of his father's business. At this time the works were chiefly engaged in the production of stoves, heating and ventilating apparatus, small engines, and machinery of various kinds. Everything Mr. Pooley touched bore the impress of thought and skill, his designs being marked by a simple elegance, a fitness, and an accuracy of taste and judgment somewhat unusual in those early days, before Schools of Art had lent their aid to the student. Correctness of outline, strength of form, with lightness of appearance, were aimed at and generally attained by him. About the year 1830 his father admitted him to a partnership, and the firm then took the style of Henry Pooley and Son.

Trifles—at least what appear to be such at the time—often influence the whole course of men's lives: it was so in Mr. Pooley's business career; for, about the year 1832, he was induced to commence the manufacture of weighing machines as a somewhat unimportant addition to his business, little thinking that this step would largely vary the character of his operations. But the construction of the Liverpool and Manchester railway, quickly followed by the projection and completion of other lines, opened up a new business to Mr. Pooley's enterprise.

These undertakings demanded novel contrivances for handling and rapidly weighing goods brought for conveyance: his quick perception and ready resource enabled him to anticipate the special requirements of this new trade, and to contrive appliances for weighing the goods, &c., traffic, which railway engineers and managers were not slow to appreciate and to use. His apparatus served as models, which others quickly copied and imitated; but nevertheless his business extended rapidly. By his father's death, in the year 1841, he was left at the head of a large concern, which

in its management drew heavily on his energy and activity. About this time his friend, Mr. Joseph Franklin, the then surveyor to the corporation of Liverpool, requested his advice and assistance in preparing the engineering plans and details required for the erection of the public baths and washhouses, Frederick Street, Liverpool, and these were freely given. It is believed that this establishment, which was regarded somewhat as an experiment, was the first of the kind ever erected in the United Kingdom. Proving to be so entirely successful, the corporation resolved on the erection of the larger and more important institution in Paul Street, the centre of a poor and squalid district in Liverpool. Again Mr. Franklin asked Mr. Pooley's services, and the arrangements connected with water service, tanks, boilers, drying closets, distribution of steam, hot water, and many of the details connected with the private and plunge baths, were planned and afterwards executed by him. He entered into this work *con amore*, for sanitary science and reform had early been studied and advocated by him. For some years after the erection of these baths his advice was frequently sought in reference to similar projects. He planned and carried out the whole of the works in the erection of the public baths and washhouses at Chester, including the water supply, filtering beds, and storage. The Chester plunge bath was at that time (1849) the largest in the kingdom. The engineering details of the first Macclesfield and other public baths were also his work. In 1846 Mr. Trevithick, the then locomotive superintendent at Crewe, consulted him on the subject of balancing locomotive engines by actual weight; and he arranged and made the first multiple weighing apparatus ever used for this purpose. It was embodied in the patent taken out by him in 1847, "for improvements in weighing machines." The railway wagon weighbridge was greatly simplified and improved by him; the parts were framed together in a new and very secure manner, thus reducing its cost and the cost of its foundation work. A weighing crane was also invented by him, but this was not a very successful application. In 1848 he commenced to take a prominent part in public affairs within his own parish of Wallasey, a large one, on the Cheshire side of the Mersey; and not long afterwards he was elected to the Improvement Commissioners Board of this important district. The Commissioners were entitled to send one of their body to represent them on the original Birkenhead Dock Board, and Mr. Pooley for a time occupied the position of representative. Road communication within the parish was formerly in a deplorable state, and he early stimulated his colleagues into action;

roads were made, a system of main drainage was devised, a public water supply projected, which was carried out under the professional direction of Mr. Robert Rawlinson, M. Inst. C.E.; gas works were established, ferry rights acquired, and communication with Liverpool much improved. The landing pier at New Brighton was completed by Mr. W. Carson, M. Inst. C.E.,[1] from whose designs the Egremont ferry was also reconstructed. The foregoing works were not carried out without much ignorant opposition; but his indomitable energy, his excellent and persuasive manner and address, materially aided his colleagues to overcome all obstacles. He was several times elected chairman of the Wallasey Local Board.

A few Papers were written and published by him; among them one of considerable interest on "The Public Health." Always an ardent friend of education, he was elected as a member of the first School Board for Liverpool. After serving his term of office he retired from the Board, but he did not cease from work. His friend, Mr. C. Bushell (the chairman of the first School Board), conceived and carried out a scheme for connecting the primary and higher class public schools of the town; and, under the direction of a council, called the Liverpool Council of Education, this comprehensive arrangement was put into operation. Mr. Pooley served on this council, and in connection with it he founded a science scholarship. He retired from active business life in 1872. In 1876 he celebrated his golden wedding by the gift of a new school to the village of Seacombe (parish of Wallasey), in connection with the Wesleyan church, of which he was a member.

Mr. Pooley was a man of large heart and catholic spirit, and was always ready to aid with brain and purse the cause of religion, science, and education. He was an excellent and fluent speaker. As chairman of the Ferry Works Committee of the Wallasey Local Board, he was engaged in his duties up to four days before his death, when he discussed with the Board's Engineer, Mr. Carson, the progress of the new ferry works now in construction at Seacombe—works of a comprehensive and important character, whether viewed as the main outlet from the parish, and therefore its chief public work, or in the light of the large expenditure involved. As one of the principal promoters of these works, Mr. Pooley's clearness of perception, firmness of grasp, and readiness of resource, came prominently into view. It might be said that he died literally in harness, having lived a most un-

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lii., p. 239.

selfish life, earnestly desiring and contributing to the improvement of his fellows, more particularly in the parish of Wallasey, in which he resided for thirty-four years. His early opportunities for self-improvement were small, but he used them well; and, firmly believing in a life of continued and progressive education, always learning himself, he was ever ready with some new views, wide and far-sighted ideas, often much in advance of his time. In his habits he was simple; always an early riser, he spent the first hours of each day in his study.

He died at his residence, Home Cross, Liscard, Cheshire, on the 1st of September, 1878. Mr. Pooley was elected an Associate of the Institution of Civil Engineers on the 21st of January, 1851.

---

MAJOR GEORGE SWETENHAM was educated at the Royal Military Academy, Woolwich, and entered the corps of Royal Engineers on the 7th of April, 1856. After serving in the mutiny campaign of 1858, on the amalgamation of the three Indian corps of Engineers with that of the Royal army, he joined the Public Works Department, as second grade Assistant Engineer, in January 1859, he being the first officer of the Royal corps who joined the Public Works Department of India. In April 1865 he attained to the rank of Executive Engineer, third grade, and in April 1866 was promoted to the second grade. Up to this date he had been employed chiefly on military buildings at Fyzabad, in Oudh. He was then transferred to Hyderabad (Dekkan), and was in March 1868 raised to first grade Executive Engineer. During these ten years he on several occasions officiated as Superintending Engineer and Secretary to the Resident of Hyderabad in the Public Works Department. As an Executive Engineer during this period he was wholly employed in the construction of military buildings in the large cantonments of Secunderabad and Trimulgherry, and was the first to introduce granite, the material now generally used for these buildings. He rendered efficient service to the Government of India, which was on several occasions officially acknowledged. As a military officer Major Swetenham possessed excellent abilities, being energetic and taking great interest in his work. He was wounded at the capture of Lucknow, and obtained a medal for services during the Indian mutiny, with the clasp for the capture of Lucknow.

Major Swetenham was elected an Associate of the Institution of Civil Engineers on the 23rd of May, 1871. He died of cholera, on the 10th of July, 1878, at Bolarum.

---

SIR FREDERICK MARTIN WILLIAMS, Bart., M.P., son of William Williams, of Tregallow, created a baronet in the year 1866, was born in January 1830. He was educated at Winchester, and in 1858 married a daughter of the Rev. R. V. Law, Rector of Christian-Molford, Wiltshire. He was first elected to represent the Conservative interest in Truro in 1865, and succeeded his father in the baronetcy in March 1870. He was a partner in the Cornish Bank, in the tin-smelting firm of W. F. and G. Williams, in the Williams' Portreath Company, carrying on a large business in coal and other merchandise; a partner in Williams' Perran Foundry Company, and in Williams' Perran Company, and was largely interested in Cornish mines, and in the clayworks of the county. He was also connected with insurance companies, and a director of the Cornwall Railway Company. He was president of the Royal Cornwall Agricultural Society for the year 1877-78. As a Freemason, Sir F. M. Williams was well known and highly respected. In his own social circle he was looked upon as a man of taste and refinement, a patron of the fine arts, a princely host, and a generous friend of the poor. He died rather suddenly, of apoplexy, when about to take part in a shooting expedition on his estate at Heanton, near Barnstaple, on the 3rd of September, 1878. Sir Frederick M. Williams was elected an Associate of the Institution of Civil Engineers on the 9th of April, 1872.

SECT. III.

# ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

## *Regulations for the Uniform Supply and Testing of Portland Cement.*

(Journal für Gasbeleuchtung, 1878, p. 546.)

ACCORDING to the resolutions passed by the Berlin Society of Architects, the Berlin Society of Contractors, the German Society for the Manufacture of Bricks, Lime, and Cement, and the Society of German Cement Makers, the barrels of cement are to be uniform in weight = 180 kilogrammes gross, and 170 kilogrammes net; half barrels 90 kilogrammes gross, 83 kilogrammes net; sacks 60 kilogrammes gross; 2 per cent. to be allowed for inequality in weighing and loss by leakage. All sacks and barrels to have the names of the manufacturers and the gross weight marked upon them. The use of the 200-kilogrammes barrel is to be permitted until the end of 1879. Portland cement may be ordered slow or quick setting. Slow setting cement is to be preferred on account of its more trustworthy hardening and greater strength. A cement setting in half an hour or more is to be considered slow. All comparative tests should be made at 15°–18° C. (59°–64° Fahr.), or the temperature should at any rate be taken into consideration. Slow-setting cement must not get warm when setting—quick, may. Portland cement becomes slower setting by keeping, and becomes stronger also if stored in a dry place free from draughts. It must not alter in bulk when gauged, and should not show any cracks after immersion in water. Quick-setting cement samples may be immersed a quarter of an hour after gauging; slow-setting ones should sometimes not be put in water until twenty-four hours after mixing. Cement which cracks decreases in strength. If gauged on a dry tile, which has been previously wetted, the sample pats should adhere to it firmly. Portland cement should be ground so finely that a sieve of 5,800 meshes per square inch rejects at most 25 per cent. As cement is used with sand, and such mortar is stronger the finer the cement, it is necessary that it should be ground extremely fine that a greater number of particles may come into effect. It would be erroneous, however, to judge cement only by its degree of fineness. Well-burnt cement coarsely ground is stronger than soft clayey fine. The strength of cement is to be

tested, mixed with sand, in a uniform manner. The briquettes are all to be of the same shape, having a section of 0·77 square inch, and are to be tested in the same machines. Experience shows that the cement of different makers cannot be compared satisfactorily when gauged neat. Cement is used in compression, and is not tested in this way on account of the cost of machines for doing so. In order to insure uniformity it is recommended that only the machines designed by the President of the Society of German Cement Makers be used. Good Portland cement, when mixed with 3 parts (by weight) of clean sharp sand, should, after twenty-seven days in water and one in air, stand a minimum tensile strain of 113·7 lbs. per square inch. Higher tests may be required for certain purposes. The sand used is to pass a 60-mesh sieve and to be rejected by a 120 mesh. The briquettes are to be broken immediately upon removal from the water. Quick-setting cement must not be expected to bear 113 lbs. when thus tested. The sand used for testing should be free from loamy particles, and prepared in a uniform manner, as the degree of coarseness influences the results. The seven days test may be used in combination with the twenty-eight days as a further guide. Tests should if possible be extended over some months or years. The briquettes should all be exposed to the air for a uniform period of twenty-four hours before immersion, as the duration of such exposure affects the strength. The briquettes should all be made in the following manner: A strip of thin wetted blotting-paper should be placed under each mould on a slab of metal or marble. Five well-cleaned and wetted moulds should be carefully filled with the following mixture: 8·75 ozs. of cement and 26·25 ozs. of normal sand, mixed first dry, and then with 6·1 cubic inches of water. At least ten briquettes should be made for each test, the average of which is taken, but if any very low breakages are recorded they are not counted. Briquettes may be gauged on permeable plates, and when made thus give higher results than those on impermeable ones. The mixture for neat samples on impermeable plates should be 1,000 parts (by weight) of cement to 200 to 275 parts of water according to the time of setting. That for permeable plates, 1,000 parts of cement (by weight) to 330 of water.

V. de M.

---

## *Excavations and Foundations in Sand for Works on the Sea Coast of the Department du Nord, France.* By M. Plocq.

(Annales des Ponts et Chaussées, vol. xvi., p. 373.)

Several locks and sluices constructed in the last few years at the ports of Dunkirk and Gravelines have been founded on a bed of fine sand, which extends to a depth of more than 50 feet below low water of spring tides. In carrying out these works, and also the excavation and quay walls of the adjoining docks, the method of shutting out the tide by cofferdams and pumping out the water

at once, was adopted in preference to employing dredgers for removing the upper portions of the excavation. The engines used were from 8 to 10 HP., and by having two for each work the pumping continued uninterruptedly. The sumps were made by sinking cylinders of wood or iron as the excavation for the works was carried down, the sinking being stopped about 3¼ feet below the lowest depth of the foundations. The bottom of the sump was then closed, and the water allowed to flow in from above through holes in the sides. By this means, and also with the precaution always adopted of placing the pumps from 50 to 65 feet away from the nearest part of the foundations, the pumping could be carried on without any danger of drawing away the sand from under the foundations. The earthwork was removed in wagons by locomotives at the rate of from 2,000 to 2,600 cubic yards per day. When the foundations were ready, the water was allowed to rise to within 8 inches or a foot of the proposed level of the upper surface of the concrete, to provide against any danger from the water oozing up through the newly laid material and disintegrating it. The concrete was gently deposited from skips or through a funnel till it rose above the surface of the water. It was then tipped in from barrows or wagons on the top of the first heap, being levelled and beaten down by men with spades and rammers. The concrete was thus gradually extended over the foundations under water with as little exposure to the water as possible, and was deposited at the rate of about 260 cubic yards a day. Special care was also taken throughout the operation to lead the water from the farther parts of the works to the pumps, so that it should not percolate through the concrete. The advantages of this system over that of a partial excavation in the first instance by dredging are, that piling under and round the foundations, or concreting, can be commenced directly any portion of the excavation has been carried down to the proper depth, and a good deal of time thereby saved; and that the necessary plant is much less, as in dredging the machines are required in addition to the pumps which must eventually be employed. The cost of excavation by the method described is reckoned altogether at 2·35*d.* per cubic yard, which is less than half the cost of excavating by the aid of dredgers. L. V. H.

---

## *On the Nature of Soils, and on Slips in Clay Soils.*[1]

By R. LEFEBVRE.

(Annales des Ponts et Chaussées, vol. xvi., p. 390.)

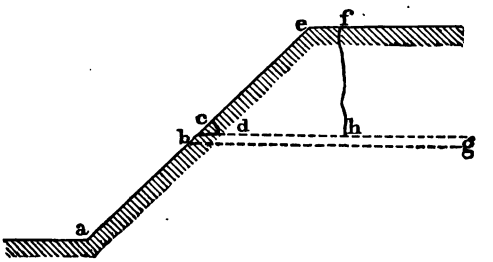
The Author commences by enumerating the varieties in the physical properties of soils, and the different capacities they possess, under various conditions of moisture, of letting water percolate

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. i., p. 112.

through them. Compact soils only admit of the passage of water through fissures; and the Author attributes slips in clay soils to the action of water in the fissures produced in dry weather. Disruptions in clay constantly occur, and occasionally the water, penetrating to a great depth, exerts a powerful hydrostatic pressure.

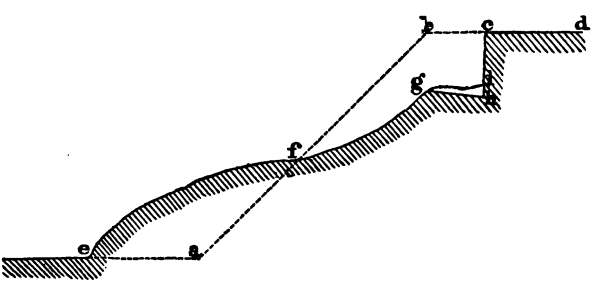
The causes of slips in cuttings and embankments of clayey soil are different. When a cutting is excavated where a very permeable stratum intervenes between the surface soil and a bed of clay, the thin layer of water, which accumulates on the top of the clay, is tapped and flows down the slope. The flow of water along the permeable stratum, *b*, *g* (Fig. 1), washes away some of the

FIG. 1.




sand or gravel, and causes the fall of a portion, *b c d*, of the upper soil, which gradually chokes up the passage and stops the flow. The water then, in wet weather, rises behind in the fissures of the top soil, and the hydrostatic pressure, aided by the softening of the surface of the clay, detaches a mass, *c e f h;* the water in the fissures lowers, and the movement of the mass then ceases till rain falls again, when the mass above disintegrates the moistened clay and produces a slip. The slip is generally of the form *e f g h*, shown on Fig. 2; the top surface of the slip remains sometimes horizontal, as at *g i*, but sometimes it slopes away from the cutting, as at *g h*.

FIG. 2.




This position could not result from the mere disintegration of the

clay, as the clay would be more liable to be disintegrated at the surface of the slope than at the back, whereas the action of hydrostatic pressure would fully account for the form assumed by the slip. The water-bearing stratum above the clay keeps it generally moist, and prevents the formation of fissures; but when there is no permeable stratum in which water can collect, fissures are liable to be found in the dry clay, and the rain filling these fissures either produces a rapid disintegration of the clay, or, gradually penetrating deeper into hidden fissures, at length forces a considerable mass of clay into the cutting, and the detached mass, though fairly solid at first, soon becomes soft by exposure to wet; and this result has led to the supposition that slips were due to disintegration by wet and the weight of the earth above.

Slips in clay embankments not thoroughly consolidated, are mainly caused by the disintegration by wet of the lower portions of the clay. The rain penetrates without difficulty through the spaces between the lumps in the embankment, and the weight of the mass above, pressing upon the slippery semi-fluid bottom portion, produces a slip. The hydrostatic pressure, however, comes also into play as the embankment consolidates; and when the embankment has finally settled into a fairly compact mass, it approaches in nature to the original soil, and the hydrostatic pressure becomes the principal disturbing cause.

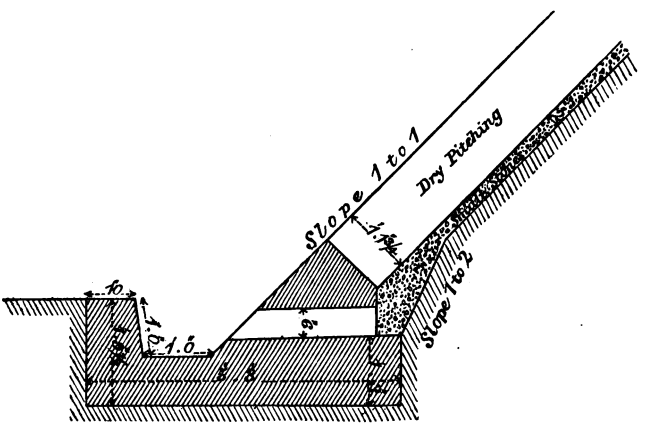
As the theory indicated above shows that the action of water is the primary cause of slips, it is evident that the surest means of preventing slips would be to stop, as far as possible, the penetration of water far into clay soils near cuttings or in embankments, and to facilitate the escape of whatever water may have got in. It is accordingly advisable to drain by trenches the surface soil above a clay bed, so that the rain falling on it may not penetrate to the fissures in the clay. When a layer of very permeable soil lies between the clay bed and the top soil, it is only necessary to ensure the discharge of the water collecting in this layer by forming trenches filled with stones at the outcrop of this layer in the cutting, which would both afford a ready passage for the water, and also prevent the fall of the portion of the upper soil, *b c d* (Fig. 1), at the mouth of the permeable layer. If there is no permeable layer overlying the clay, it is very important to drain the upper soil as effectually as possible, and if necessary an external counter-pressure must be afforded to the internal pressure of water by weighting the slope with pitching. It is always advisable to protect the slopes of the cutting by a covering of soil, turf, or pitching, to protect them from atmospheric influences which tend to create fissures; and between the clay surface and the covering a very permeable layer must be placed, so as to carry away the water penetrating the covering.

As much less force is required to prevent the occurrence of a slip than to arrest its progress when commenced, it is most important, in cuttings where considerable slips are apprehended, to put the pitching on the slopes as soon as possible, and, particu-

larly, not to allow a winter to elapse between the opening of a cutting and its protection.

The Author does not approve of the plan of draining the slopes of a clay cutting by drains filled with stones, as he considers that, not only is it an ineffectual remedy against slips, but, by tending to detach the mass of clay, it rather aids the occurrence of slips. The method adopted by the Author in two cuttings on the Epinay and Luzarches railway, made in the clay beds overlying the gypsum of the Paris basin, for securing them against slips, some large ones having occurred during the progress of the excavations, is shown on Fig. 3. The slopes were weighted with dry pitching, with a

FIG. 3.




filtering bed behind, from the bottom of which the water was conveyed into the open stone culvert at the base of the slope by outlets, placed about 16½ feet apart. If under similar conditions it is necessary, for the sake of economy, to dispense with pitching and use soil or turf instead, the layer should be made thicker to afford sufficient weight, and the filtering bed must also be made thicker to provide against obstruction, and the slope made flatter.

The plan proposed by the Author for securing unconsolidated embankments against slips, which he has applied with success in one instance, is to drain thoroughly the bottom of the embankment with trenches, filled with stones or gravel, across the base of the embankment, and placing a layer of stones over the surface of the ground under the embankment, and forming this surface so as to fall towards the drains. This arrangement prevents the softening of the clay at the base of the embankment by wet; and when the settlement of the mass has stopped, the slopes may be protected by a covering of soil or turf, and in exceptional instances by pitching, with a filtering layer below the covering.

L. V. H.

## *On the Determination of the Stresses permissible in Structures.*

By J. SEEFEHLNER.

(Zeitschrift des Oest. Ingenieur- und Architekten-Vereins, vol. xxx., p. 148.)

The Author proposes to express the results of Wöhler's researches in a manner more simple than that adopted by Winkler.

Let $\epsilon = \frac{P^{min}}{P_{max}}$, the ratio of the extreme stresses to which a bar is subjected, the stresses having their proper sign, so that $\epsilon$ may be + or −. Further, let $t$ be the statical immediate breaking strength, $a$ the working strength, $u$ the breaking strength for an indefinitely repeated stress of one kind, $s$ the breaking strength for indefinitely repeated stresses of equal amount and opposite sign.[1] Then generally,

$$a = \alpha t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

For pressure or tension only, from previous researches,

$$a = u\left(1 + \frac{t - u}{u}\epsilon\right),$$

and experiments give $u = \frac{2}{3}t$. Hence,

$$a = \frac{2}{3}\left(1 + \frac{\epsilon}{2}\right).$$

For pressure and tension alternately,

$$a = u\left(1 + \frac{u - s}{u}\epsilon\right),$$

where $\epsilon$ is negative, and $u = 2s$. Hence,

$$a = \frac{2}{3}\left(1 + \frac{\epsilon}{2}\right),$$

which is the same expression as before.

If the influence of the shocks due to the moving load is allowed for by a factor of safety $\beta$, it may be noted that this co-efficient should be larger for small bridges and less for bridges of great

---

[1] There are no English equivalents for the terms now adopted in Germany, *Tragfestigkeit*, *Ursprunglichkeit*, and *Schwingungsfestigkeit*. Thurston, in the translation of Weyrauch, gives for $t$, the term "carrying strength"; for $u$, the term "primitive safe stress"; and for $s$, the term "vibration safe stress." These are not very expressive.—W. C. U.

span. Since from Wöhler's researches it appears that with the decrease of the difference of the maximum and minimum stresses the working strength increases, it may be assumed that

$$\beta = A - B\epsilon \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where A and B are constants yet to be determined. Then from (1) and (2) the permissible stress is found to be

$$k = \frac{at}{\beta} = \frac{2}{3} \cdot \frac{1 + \frac{\epsilon}{2}}{A - B\epsilon} \cdot t \quad . \quad . \quad . \quad (3)$$

Since, from the circumstance already mentioned, $k$ is to be less for small bridges than for large ones, and giving attention to the values already selected by Launhardt, Weyrauch, Winkler, and Gerber, the Author takes A = 4 and B = 1·6 for a normal material. Hence, if $t$ is 3,600 kilogrammes per square centimètre (51,200 lbs. per square inch), then for $\epsilon = 0$, $k = 600$ kilogrammes (8,530 lbs.) and for $\epsilon = 1$, $k = 1{,}500$ kilogrammes (21,300 lbs.)

The Author then compares the stresses given by his formula with those given by the authors named above, and finds a substantial agreement. The following abstract of part of the comparison may be useful, the stresses being in lbs. per square inch:

SAFE STRESS for TENSION ONLY.

| — | $\epsilon = 0$. | $\epsilon = \frac{1}{4}$. | $\epsilon = \frac{1}{2}$. | $\epsilon = \frac{3}{4}$. | $\epsilon = 1$. |
|---|---|---|---|---|---|
| Winkler . . . . . | 8,406 | 9,814 | 11,820 | 14,820 | 19,912 |
| Seefehlner . . . . | 8,534 | 10,667 | 13,327 | 16,754 | 22,757 |

SAFE STRESS for TENSION and PRESSURE.

| — | $\epsilon = 0$. | $\epsilon = -\frac{1}{4}$. | $\epsilon = -\frac{1}{2}$. | $\epsilon = -\frac{3}{4}$. | $\epsilon = -1$. |
|---|---|---|---|---|---|
| Winkler . . . . . | 8,406 | 7,538 | 6,841 | 6,258 | 5,774 |
| Seefehlner . . . . | 8,534 | 6,785 | 5,334 | 4,096 | 3,044 |

The Author thinks his expression is more convenient and simple, and as accurately agrees with experiment as those previously given. It is as general, and rests on no more hypotheses.

W. C. U.

## *Determination of the Thickness and Form of the Arches of Stone Bridges.* By G. TOLKMITT.

(Zeitschrift des Architekten- und Ingenieur-Vereins zu Hannover, vol. xxiv., p. 451.)

The thickness necessary for the arch of a stone bridge depends on the strength of the material of which the arch is built, the load it has to bear, and the form and dimensions adopted for the arch-ring. All empirical formulæ used for determining the depth at the crown which do not contain these three factors, can only be regarded as giving adequate approximation when applied within narrow limits. If the span of the arch be small, and the backing above it of little depth, it is necessary besides to take account of a partial distribution of the live load. It may generally be said, that the thickness required will be least when the form chosen for the arch is such as to make the line of pressure which corresponds to full loading coincide with the mean line of the arch-ring. In a former paper, published in the "Zeitschrift für Bauwesen" of 1876, the Author has gone fully into this question; and the results then obtained have been collected and reproduced in a small table appended to the present paper. This table gives, with the aid of elements depending on the three factors named, a series of co-ordinates of the curve of the intrados. The chief object of the present paper is, however, to establish a formula which, while taking due account of the three factors, gives also an easy means of determining the thickness at the crown of such arches. The formula is not strictly accurate, but numerous applications which have been made of it have proved that the approximation, even in extreme cases, is very great.

The Author examines two distinct cases: 1st. The evenly distributed live load, covering the entire length of the span. 2nd. The live load extending only from one of the abutments to the centre of the arch. The latter case leads generally to greater thicknesses than the first, but still it is always advisable to try both hypotheses. If $c$ be the thickness at crown, it can be expressed in the first case by

$$c = \frac{\cdot 15 \times \frac{w^2}{f}}{q - \cdot 15 \frac{w}{f}} \left( e + p + \frac{f}{10} \right).$$

$e$, depth at crown of the surface, representing the permanent load on the arch. It is comprised between the extrados and a horizontal line above it.

$p$, depth of horizontal strip, representing the live load.

$w$ and $f$, span and rise of the intrados of the arch.

$q$, greatest pressure admissible on the stone.

The formula is independent of the choice of unit, which may be at pleasure the foot, the yard, or the mètre. Although $q$ is equivalent

to a weight, it is not to be expressed by a number of units of weight, but by the volume of stone of a like weight. Thus, supposing the stone to be able to bear safely 80 tons per square mètre, and to weigh 2 tons per cubic mètre, the numerical value of $q$ to be introduced into the formula will be $\frac{80}{2} = 40$ cubic mètres.

In the second case, that of partial distribution of the live load, the expression of $c$ depends on the nature of the assumption which is made with regard to the springings. When they are assumed as rigidly fixed the value of $c$ will be smaller than when they are supposed to admit of slight angular displacements. It is therefore judicious to adopt the second hypothesis, although probably farther from the truth than the first. The equation becomes in this case,

$$c = \cdot 625 \times p \frac{f}{c + e + \frac{p}{2} + \frac{f}{10}} \times \frac{2w - f}{2w}.$$

The symbols have the same signification as before. The thickness at the crown being computed, there remains to draw the arch in its right form. This is done by means of the table already cited. The operation is extremely simple, reducing itself to the multiplication by numerical co-efficients of a series of figures contained in the table. To further elucidate the process the Author appends a numerical example.

A. O. B.

---

## *On the Strains produced in Arched Drawbridges by Wind-pressure.* By R. KOHFAHL.

(Civilingenieur, vol. xxiii., p. 577.)

If an arched drawbridge is exposed to wind impinging upon it horizontally, the ends of the windward girders will abut against each other at the crown of the arch, while those of the leeward girders will tend to open.

The entire pressure against the face of the arch may be supposed to be divided into single pressures acting horizontally on the joints of the straight upper and the curved lower members. Now as there exists a rigid connection between each upper girder and the opposite arched rib, and as the joints of the arches are likewise firmly connected by weather-bracing, all these pressures are transmitted to the joints of the arched ribs, and in the following investigations they have been used in this form only.

The arch is parabolic, and divided into panels, each of a length $= a$, their number being $= 2\ m$, and the span of the bridge $= 2\ m \times a$. The distance apart of the two main girders (width of the bridge) is $= b$, and the vertical height of the apex above the

springing = $h$. The dead weight of the arch, and the reactions and tensions, resulting from it, are left out of consideration.

Each of the joints of the semi-arch, from 1 to $m-1$, is subject to a horizontal wind-pressure = P, the pressure on each of the four points 0 and $m$ being $= \frac{P}{2}$, these latter being transmitted direct to the masonry. The support of the leeward rib developes the following reactions:—

1. A horizontal reaction R, acting in the direction of the pressures P, P, and constituting a couple with the resultant of the latter.

$$R = P\frac{2m-1}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

2. A horizontal reaction $H_1$ acting at right angles to R, equal and parallel to the pressure in the crown joint between the two windward girders, but opposite in direction. These pressures form a couple whose moment, about a vertical line, balances the horizontal component of the couple in (1) formed by the reaction R and the resultant of the wind pressures on the semi-arch.

$$H = P\frac{a}{b}\frac{m^2}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

3. A vertical reaction $V_1$ equal and parallel, but opposite to the downward pressure $V^1$ by which the point $A^1$ of the windward girder is held down; these form a couple balancing the vertical component of the couple in (1) formed by the reaction R and the resultant of the wind pressures on the semi-arch.

$$V = P\frac{h}{b}\frac{4m^2-1}{6m} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The stresses $U_n$ and $U'_n$ in the curved members (in the direction of the tangent), in the tie-rods $D_n$, and in the struts $N_n$, are determined *for the $n^{th}$ joint* as follows:—

$$U_n = -\frac{1}{\cos\alpha_n}P\frac{a}{b}\frac{(m+1-n)^2}{2} \quad . \quad . \quad (4)$$

$$U^1{}_n = -\frac{1}{\cos\alpha_n}P\frac{a}{b}\frac{n(2m-n)}{2} \quad . \quad . \quad . \quad (5)$$

$$D_n = \frac{1}{\cos\beta_n}P\frac{2m+1-2n}{2} \quad . \quad . \quad . \quad (6)$$

$$N_n = -P\frac{2m+1-2n}{2} \quad . \quad . \quad . \quad . \quad (7)$$

Where $\alpha_n$ is the angle the arched rib makes with the horizontal at that joint and $\beta_n$ the angle between the corresponding strut and tie of the weather-bracing at the joint. Besides these tensions

a vertical (upward) pressure (Q and $Q^1$) results for each joint, which, for joint $n$, is determined as follows :—

$$Q_n = P \frac{h}{b}\left(\frac{m-n}{m}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

$$Q^1{}_n = P \frac{h}{b} \frac{n(2m-n)}{m^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Consequently, besides the arch ribs, and the ties and struts between them, there are other constructive parts requisite to resist these upward pressures. This is supplied by the straight upper members, and the vertical and diagonal bracing between them and the arched ribs.

The case of a partial load by wind pressure (occasioned by some object moving along the bridge being exposed to the wind) is considered next, and equations given for the determination of the stresses produced.

In order to illustrate these investigations by a numerical example, a bridge of 40 mètres span is selected, which has been described in Prof. Ritter's well-known work, "Dach- und Brücken-Constructionen." The principal dimensions are—

$$a = 2^m,\ h = 5^m,\ b = 4^m,\ m = 10.$$

The lateral surface of the arches exposed to the wind has been taken as a rectangle of $2^m \times 40^m$, that of the moving load (a railway train) as 3 mètres high. Supposed the pressure of wind per square mètre to be = 100 kilogrammes, then—

the permanent wind pressure = $2 \times 2 \times 0{\cdot}1 = 0{\cdot}4$ tons.
the moving „ „ = $2 \times 3 \times 0{\cdot}1 = 0{\cdot}6$ „

for each panel of the bridge.

The calculation of the strains produced by both pressures is carried on at some length, and the results of the vertical upward pressures Q and $Q_1$ on the upper girders and the vertical and diagonal bracings of the arches, are determined, the comparative importance of the foregoing investigations being rendered more apparent by the tabulation of the stresses due to wind pressure as percentages of those due to load.

A. H.

---

## *Iron Bridge over the River Inn at Königswart, near Wasserburg.*

By C. Schnorr v. Carolsfeld and A. Rottmüller.

(Zeitschrift für Baukunde, vol. i., p. 225.)

At the site of the Königswart bridge the River Inn is 394 feet wide, the banks sloping upwards at 1½ to 1 to the level ground, which on the left bank is about 108 feet, and on the right bank

138 feet above low water. The general character of the geological formation is diluvial, the river bed cutting into the tertiary flint to a depth of from 10 to 26 feet, the flint being overlaid by a thick stratum of gravel, interspersed with bands of clay and conglomerate with erratic boulders. The rail level is 161 feet above the bed of the river. The bridge is divided into three main spans, each 215 feet in the clear, with a side opening of 87 feet 3 inches on the left bank, and one of 61 feet 9 inches on the right bank. The whole width of the valley (902 feet at the high level) is bridged, embankments being dispensed with, in view of the possibility of land slips. The abutments are built on the natural surface of the ground, where a thoroughly good foundation could be obtained. The piers and abutments, constructed for a double line, are of the simplest character, in consideration of the isolated position of the works and the nature of the stone available. The girders throughout are of the 'Zugband' type with parallel flanges, for single line, those in the main spans being 27 feet 6 inches deep. Before commencing the foundations for the river piers, borings at various points were made down to the flint. For this purpose, piles of from 20 to 25 feet long were, before being driven, bored out longitudinally to within a distance of 2 feet of their points; and being then driven down to the upper surface of the flint, this lower length of 2 feet was removed by means of an augur, and the boring then carried into the flint to depths of as much as 44 feet, the time occupied varying from $1\frac{1}{2}$ to $7\frac{1}{2}$ minutes per foot, the results proving that, at a depth of 11 feet 6 inches to 13 feet, a good foundation was to be obtained. The ground at the site of the left-bank land pier being full of springs, deep trenches were cut, and the soil thereby thoroughly drained.

The stone was brought up by river, a landing wharf, with tramways, cranes, &c., stoneyard, barracks for two hundred workmen, and other temporary works, being erected in the immediate neighbourhood of the bridge site. For the transport of material from the left bank to the works on the opposite side, a temporary bridge, carrying two lines of rails, was erected, the central portion of which was spanned by two girders of the Howe type, allowing a headway of 19 feet 9 inches for the passage of river craft. At each end of this temporary bridge was an inclined wire tramway, worked by two winding engines, by which the material for the land piers and abutments was conveyed to the high ground.

The stone used is conglomerate 'nagelfluhe' (pudding stone), the girder bed-stones and the pier caps being of granite. For the foundations of each river pier a double row of sheet piling, 10 inches by 10 inches section, was driven, enclosing an area of 72 feet by 33 feet. The outer and inner rows were 6 feet 6 inches apart, the intervening space being filled up with concrete to a height of 5 feet above low-water level. It being found that these piles could only be driven to a depth of from 3 feet 3 inches to 5 feet into the flint, their points thus being at least 1 foot 6 inches above the bottom of the excavation, the precaution was taken of leaving

a footing of earth around the interior, which later on was removed piece-meal as the concrete foundation was put in, the boulders being removed when necessary by crowbars or blasting. When the dams were completed, the water was removed by centrifugal pumps; concrete 6 feet 6 inches in thickness was deposited, and the masonry continued up to high-water level, when the piles were removed and the intermediate space between the pier and the concrete dam filled in. The foundations of the river piers were begun in October 1872; the masonry was finished up to high-water level in May 1873, and the whole of the masonry was completed by the end of April 1875. The erection of the girders (constructed by the South-German Bridge Works Company, under the direction of Mr. Gerber),[1] was commenced in December 1875, and finished in February 1876, and they were tested in the following month. For this purpose five coupled locomotives of the heaviest type were used, equivalent to a load of 1·32 ton per lineal foot. As a stationary load, these produced a deflection in the main girders of $1\frac{1}{4}$ inch, and a permanent set of $\frac{1}{8}$ inch. As a running load (at express speed) a lateral deflection was produced of $\frac{1}{10}$ inch, the vertical deflection being the same as that produced by a stationary load.

The following table shows the quantities of some of the materials used:—

| | |
|---|---|
| Timber for poles, staging, &c. | 68,867 cubic feet. |
| Ashlar | 296,670 „ |
| Rubble | 184,352 „ |
| Granite | 10,807 „ |
| Portland and hydraulic cement | 1,300 metric tons. |
| Wrought iron for girders | 735·4 „ |
| Cast „ „ | 20·4 „ |
| Steel „ | 2·3 „ |
| Lead „ | 12·75 cwt. |

The cost was as follows:—

| | £. |
|---|---|
| Construction of wharves, cost of cranes, &c., and erection of temporary buildings at Königswart. | 3,775 |
| Ditto near Brannenberg | 1,020 |
| Construction of temporary bridge over Inn, with tramways, &c. | 1,585 |
| Foundations of piers and abutments | 7,900 |
| Stone quoins and setting | 725 |
| Staging for piers and abutments | 3,640 |
| Masonry in „ „ | 38,215 |
| Girders and their erection | 26,850 |
| Supply and delivery of sleepers and permanent platform | 625 |
| Blasting for left-bank river pier | 125 |
| General expenses of supervision, &c. | 640 |
| Total | £85,100 |

D. G.

[1] *Vide* "Zeitschrift des Bayer. Architekten- und Ingenieur-Vereins," 1876, p. 1.

timber employed in the staging, some experiments were made, with the following results:—A beam $5\frac{1}{2}$ by $5\frac{1}{2}$ inches, freely resting on two supports 19 feet $8\frac{3}{16}$ inches apart, was submitted to the action of single loads at the centre. It broke with a load of $23\frac{1}{2}$ cwt., the deflection before rupture being $6\frac{5}{16}$ inches. Another beam, $6\frac{1}{8}$ by $6\frac{1}{8}$ inches, of the same span, placed in the same conditions, broke with a load of $34\frac{1}{2}$ cwt., the deflection in this case was $9\frac{7}{16}$ inches.

The main girder, for which the details have been given, weighs 82 tons $8\frac{1}{4}$ cwt. The entire superstructure, including the bearings, contains:—

947 tons 2 cwt. of wrought iron;
34 „ 17 „ of cast iron;
and 18¼ „ of steel.

The bridge was tested with a moving load of four goods engines of the heaviest description. At the centre, the greatest deflection amounted to 1·5 inch, and the permanent set, after removal of the loads, to 0·08 inch. The piers had settled 0·027 inch. The roadway bridge was tested by running over it at a quick pace four heavy road rollers, each drawn by four horses, together with about one hundred and sixty men, closely packed.

The cost of one of the river piers, including masonry up to zero watermark and the removal of the cofferdams, was £2,030, or £13 2*s.* per square yard of foundation surface. The cost of the staging of the large span, including that of the small timber girders, came to £1,906 5*s.* The total cost of the bridge amounted to £56,073, as against an estimated cost of £63,475. The first stone of the bridge was laid on the 10th of August, 1875, and it was opened on the 1st of July, 1877.

A. O. B.

---

## *Substitution of a Single Span for Two Openings of the Magdeburg Railway Bridge.* By H. Käferstein.

(Zeitschrift des Architekten- und Ingenieur-Vereins zu Hannover, vol. xxiv., p. 461.)

The Berlin, Potsdam, and Magdeburg railway bridge, over the Elbe at Magdeburg, originally comprised nine openings, two of which were spanned by a swing bridge, and the other seven by wrought-iron girders. In 1876 the local authorities granted a concession for a second railway bridge over the Elbe at Magdeburg, and in so doing imposed on the above company the obligation of removing one of the river piers of their bridge, in order to provide ampler waterway for the navigation. This decision entailed the substitution of a single span of 161 feet 4 inches for two spans of 68 feet 10 inches each. The river makes a bend at the site of the bridge; hence it was deemed advantageous to remove the river pier next the concave shore. It was necessary that the train service should be as little inter-

rupted as possible. This and the circumstance of the bridge being situate at a curve in the line, and crossing the river at an angle of 60°, materially complicated the undertaking. The new structure was put together on a disused siding, situate 710 yards from the bridge, and was loaded on to a train of rail trucks firmly coupled together. It was then taken to the bridge and secured exactly over its future place. Four piston-shaped disks, bolted to temporary brackets at the end of the main girders, supported the structure on sand contained in corresponding cylinders. The trucks and the old superstructure were removed from underneath, and the new span lowered into its place by letting out the sand. The use of sand boxes in such cases is not novel; but the Author states that it has never before been applied to a structure weighing 115 tons, nor for a fall of 9 feet 10 inches.

The main girders are of the single trellis type, with curved top flange and straight bottom flange. Their height at the centre is 23 feet, and at the ends 9 feet 10 inches. The cross girders are 10 feet 10 inches apart. After riveting up complete, the structure was lifted by means of twenty engine screw-jacks, to a height sufficient to clear the top flanges of the old girders. The bearings on the trucks were so arranged as to throw the weight as directly as possible on to the axles, thus avoiding the undue straining of the framework. They admitted also additional raising of the structure and small transverse displacements. The five trucks composing the train were well coupled up, and the engine, which could not be brought to the rear of the train, was attached to a strong chain running the whole length underneath the frames, and fastened to the last truck. In this way the risk of rupture of the couplings was avoided.

The sand cylinders were formed of a series of superposed circular cast-iron rings, 1 foot $3\frac{3}{4}$ inches high, about $\frac{3}{4}$ inch thick, and $20\frac{3}{4}$ inches in diameter. Each ring was composed of two halves, which were connected by means of flange joints. Thus, when the piston had descended below the upper ring, the latter could be removed by unbolting the joints between its halves and that between the subjacent ring. The total height of the cylinders, irrespective of a base of $9\frac{3}{4}$ inches, was 10 feet 6 inches. A rectangular channel at the base served as outlet for the sand, which reached it through a round hole 1 inch in diameter, closed or opened at will by a slide. The cylinders were filled with ordinary river sand, screened and thoroughly dried. Preliminary experiments which were made with a cylinder of 1 foot $3\frac{3}{4}$ inches diameter, both free and with 5 tons pressure, established the fact that the pressure has no perceptible effect on the flow of the sand. It was moreover ascertained that a certain amount of play could be given to the piston without inconvenience, as the sand only slightly rose in the narrow space between it and the cylinder. The weight to be carried by each cylinder was 29 tons; for greater safety, however, the cylinders were tested under the hydraulic press to a pressure of nearly 53 tons. The lowering proceeded

in a most regular and easy manner. It took about six minutes to descend the full height of a ring, not including the time required for unbolting and removing its two halves. The control over the descent was so perfect that the structure could be stopped at any given level within a fraction of $\frac{1}{8}$ inch.

In order to lose as little time as possible in removing the old superstructure, a timber staging was erected on two river barges, the dimensions of which, and the arrangements of the staging, were such as to allow of dealing with an entire span at once. The Author describes in minute detail the successive phases of the work of substitution, which occupied four days. The first train, however, passed only at 1 P.M. on the fifth day, as the morning had to be spent in testing the new structure. The various arrangements described by the Author are clearly and completely illustrated in three plates.

A. O. B.

---

## *Securing Air-Lock Doors in Sinking by Compressed Air.*

By A. HEINERCHEIDT.

(Revue universelle des Mines, vol. iii., 1878, p. 648.)

In the sinking of caissons or cofferdams for subaqueous foundations by the aid of compressed air, the ordinary pair of doors which afford access for the men from the outside into the top working chamber, and together form the air-lock, are both made to open inwards, so that the tendency of the internal air pressure is to keep them closed. But when, to save repeated openings of these doors, the excavated material is for greater convenience discharged to the outside through a shoot or spout, the door closing the inner end of this spout opens inwards, whilst that on the outer end has necessarily to be made to open outwards, the stuff in the spout preventing its being made to open inwards. As any misunderstanding of signals between the men inside the compressed-air chamber and those outside might lead to premature opening of the outside spout-door while the inside one was still unclosed, and might prove fatal to the men inside the chamber, M. Heinercheidt has devised the expedient of locking the fastening bolt of the outside door by means of a sliding pin, which is worked by a rod passing through a stuffing-box into the compressed-air chamber; the pin can be withdrawn only by the men inside the chamber, and not until they have previously closed the door on the inner end of the spout. This very simple contrivance, which secures absolute safety to the men, has been applied to air-locks employed in sinking the piers for the bridge over the Rupel at Boom, for the railway from Antwerp to Tournai.

A. B.

---

## *Memorandum on Roads, Streets, and Pavements in Victoria and Tasmania.*

(Report by C. T. HARGRAVE, Assoc. Inst. C.E., Superintendent of Main Roads, Adelaide, S.A.)

This report describes the methods employed in the construction of the roads and pavements in Melbourne and Hobart Town, together with the cost of their maintenance. The stone used for the repair of the Melbourne streets is blue basaltic rock, obtained from Merri Creek, at a distance of about 4 miles from the centre of the town; it is broken to a 2½ inch gauge by seven of Hope's stone-breakers, driven by a 35-HP. engine, and each breaking 4½ cubic yards per hour. The stone is hauled from the quarry by a winding engine of 8 HP., and tipped on to a platform, from which it is thrown by hand into the seven stone-breakers; after passing through these it is carried by flexible wrought-iron belting to an elevator, screened, and discharged into carts for removal to the town. The metal costs 4*s.* 0½*d.* per cubic yard at the quarry, and 6*s.* 7½*d.* spread. At Melbourne a steam roller is employed at the following annual cost—

| | £. | *s.* | *d.* |
|---|---|---|---|
| Allowance of 20 per cent. for wear and tear on £1,000 | 200 | 0 | 0 |
| Wages of driver and steersman, £5 2*s.* per week | 265 | 4 | 0 |
| Coals and firewood | 300 | 0 | 0 |
| Waste, oil, &c., 10*s.* per week | 26 | 0 | 0 |
| Repairs | 50 | 0 | 0 |
| Tools and contingencies | 26 | 0 | 0 |
| | £867 | 4 | 0 |

Imitation asphalt pavements are much used, and give satisfaction. Great care is taken that all the metal and screenings are well coated with tar by thoroughly mixing; for the metal it is applied cold, but heated from a boiler for the screenings. A 3-inch layer of prepared metal of 2½-inch gauge is first laid, and thoroughly consolidated by rolling; this is covered with a 1-inch layer of prepared screenings, from which the finer parts have been removed by a ¼-inch screen, and these latter are then spread to a depth of about ½ inch, and the whole finished off with a light coat of sand. The quantity of tar required amounts to 1¾ gallon per square yard of paving: the following shows the amount required for the different descriptions of materials used—

| | | | |
|---|---|---|---|
| Metal screened | 9 | gallons | per cubic yard. |
| Screenings from the machine | 22 | „ | „ |
| „ screened | 13 | „ | „ |
| „ for last coat | 38 | „ | „ |

Pavement of this description costs 2*s.* per square yard. At Launceston the footpaths are cemented at a cost of 6*s.* per square yard, as follows: A 2½-inch layer of metal is well grouted with a

mixture of 1 part of cement to 6 parts of well-washed sand; this is hand-floated to a thickness of $\frac{1}{2}$ inch with 1 part of cement to 2 parts of sand; it is then cut through with the trowel into 4-feet squares, and finished off with dry cement. The cost of the materials is—cement, per cask, 25*s.*; pure quartz sand, per load, 3*s.*; plasterer, per day, 9*s.*; labourers, 5*s.* 6*d.*; cartage, 8*s.*; broken metal, 5*s.* 6*d.* per ton.

A. T. A.

---

## *Note on the Power of Running Water to Hold Matters in Suspension.* By J. P. Frizell, C.E.

(Journal of the Franklin Institute, 1878, p. 177.)

The Author first disposes of the theory advanced by M. Dupuit, that the carrying power of water is due to the greater relative velocity of the lower laminæ of water producing different pressures upon the upper and lower sides of the suspended body, by the argument that unbalanced pressure in a mass of water must produce motion, and therefore, were not the excess of pressure maintained in equilibrium by the weight of a suspended body, upward motion of the water would result.

A solid particle, of greater density than the water in which it is immersed, never ceases to fall relatively to the water with a velocity dependent on its size and specific gravity; this velocity may be determined as follows—

Let $d$ be the diameter of the body in feet,
$v$ the velocity in feet per second,
$\rho$ the specific gravity of the material;

then the weight of the body in water $= 62{\cdot}3 \times 0{\cdot}5236\, d^3\, (\rho - 1)$

the resistance of the water $= 0{\cdot}51 \times 62{\cdot}3 \times 0{\cdot}7854\, d^2 \frac{v^2}{2g}$.

When the velocity has reached its greatest value, it becomes constant, and the resistance to motion balances the acceleration due to its weight in water. Equating the two expressions above, the value of $v$ may be found.

For a spherical mass of clay 1 foot in diameter, specific gravity $= 2$, $v = 9{\cdot}17$ feet per second; if $d = \frac{1}{100}$, $v = 0{\cdot}917$.

From this it would appear that a solid particle heavier than water, and suspended therein, never ceases to sink with the full velocity determined by its size and specific gravity. Yet such a particle may remain suspended long enough to travel considerable distances. In channels with a considerable fall, or much irregularity of surface, vertical and horizontal eddies are formed in the flowing water by the friction against the bottom and sides, and by the change in the direction of motion. Some portions of the water may thus have a considerable upward vertical velocity during part

of their course in the eddy, and this may be sufficient to annul the downward motion through the water of the particle, or convert it into an upward motion with respect to the bottom of the stream. Thus, in rapid currents flowing in irregular channels particles of a considerable size may remain suspended for some distance; while the distance that very minute particles will travel is much greater, owing to their small maximum velocity of fall through the water. To the existence of eddies, coupled with the slow rate of fall of small particles, is due, in the Author's opinion, the power of water to hold bodies heavier than itself in suspension.

A. T. A.

---

## *On the Cause of the Maximum Velocity of Water Flowing in Open Channels being Below the Surface.*[1]

By J. B. FRANCIS.

(Transactions of the American Society of Civil Engineers, vol. vii., p. 109.)

At Lowell, Massachusetts, the water drawn from the canals is in several cases gauged in what are there called "measuring flumes." These are constructed in parts of the canals where the section is rectangular, and the alignment as free from bends or other irregularities as practicable; they are simply linings of the bottom and the sides with smooth planking, retaining the direction and dimensions of the canal as nearly as possible.

The velocity of the flood in these flumes is ascertained by means of travelling floats made of tin tubes, loaded at one end with lead, so as to sink nearly to the bottom. With these tubes variations in the velocity in parts of the flume where there was no sensible change in the mean velocity are very marked.

The contact of water with the sides of a channel retards the velocity of the adjacent parts of the stream; parts more distant from the sides move more rapidly, and this difference in velocity tends to produce eddies in which the water is of course moving in all directions. One effect of this, it is believed, is to allow some of the quicker currents to penetrate those moving more slowly, and to detach masses of water from the slow currents; forcing them further from the sides, where they become the slower currents among those moving quicker.

In rectangular channels, in which the depth is less than half the width, the retarding effect of the bottom exceeds that of the sides; the eddies and other motions thus resulting must be greater in the same ratio. The effect previously described, of the quicker currents penetrating, and in this case forcing upwards, masses of the slow-moving water, must occur to a greater extent than results from the retardation caused by the sides.

Many of these slower moving masses reach the surface before

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlviii., p. 322.

fully acquiring the normal velocity, where their living force, in a vertical direction, would be expended in spreading out laterally, and, where the force was considerable, in producing the traits so frequently seen in natural watercourses. The constant recurrence of this phenomenon must cause an accumulation of water near the surface, moving with a mean velocity less than that of the water some distance from the surface. If these views are correct, there must be a constant movement of water from near the bottom of an open channel of running water to the surface; and to test this the following experiments were made in the canals at Lowell.

*Experiments in the Western Canal, July* 6, 1867.—These experiments were made in a straight reach of the canal 1,200 feet long, with a nearly uniform section, 20 feet wide at the bottom, 50 feet at the surface of the water, and about 10 feet deep.

The surface velocity was about 3·4 feet per second, and the canal as a whole was on a gravelly bed.

A tub fixed on a boat moored across the canal was attached to a 2-inch internal diameter lead pipe, terminating in an orifice pointing down stream, and about 4 inches above the bottom. Into this tub 3·1 cubic feet of whitewash was poured, a plug withdrawn, and the contents allowed to discharge at the lower orifice. Eight trials of this nature were made in which the whitewash reached the surface, at distances from the point of discharge varying from about 100 to 175 feet, the mean of the distances as recorded being 129 feet.

Other experiments were made in a deeper stream with a lesser velocity, and from these it appears that the water at the bottom of the streams came to the surface at distances varying from about 10 to 30 times the depth, the shorter distances being in the canal of least depth and most uneven bed.

J. C. I.

---

## *Observations on the Level of the Elbe in Saxony.*

By M. W. SCHMIDT.

(Civilingenieur, 1878, p. 555.)

Regular daily observations of water level have been made in the Elbe, at Dresden, since 1806, at Riesa since 1837, at Meissen since 1849, at Merschwitz, Grödel, and Strehla since 1873, and in Schandau, Königstein, Pirna, and Pillnitz since 1874. By examining the observations at those stations at which the level has been noted for a long series of years, it appears that the water level of the Elbe has in general and on the average considerably lowered, and the year 1858 appears to be the period at which this change commenced. The mean annual water level at Dresden from 1808 to 1857 was at − 5 centimètres on the gauge, and from 1858 to 1877 at − 66 centimètres, showing a lowering

of level of 61 centimètres. Similarly comparing the annual mean level at Riesa from 1838 to 1857 with that from 1858 to 1877, the latter is lower by 46 centimètres; and at Meissen, comparing the mean for 1849 to 1857 with that for 1858 to 1877, the latter is lower by 35 centimètres. Also the low summer water level has latterly not only oftener been reached, but is now considerably lower. Between 1806 and 1841 the lowest water level at Dresden generally remained within the limits — 50 and — 90 centimètres on the gauge, and only twice reached — 104 centimètres, once — 106 centimètres, and twice — 108 centimètres. Whilst in the extraordinary dry year, 1842, the lowest summer level sank to — 127 centimètres, in 1856 and 1857 it reached — 134 and — 148, and since 1858 it has varied chiefly between — 140 centimètres and — 160 centimètres. Similar results are obtained from the observations at Riesa and Meissen. The explanation of these remarkable observations must be either that the discharge of the Elbe has diminished, or that the river bed in the neighbourhood of the gauges is considerably deepened.

Works for regulating the stream below the gauge at Dresden between 1847 and 1850 undoubtedly led to a deepening of the stream below and in the neighbourhood of the Dresden gauge, and a similar deepening has resulted at Riesa from regulating works between 1863 and 1869, and at similar works between 1871 and 1872. The Author then discusses various observations, which tend to show that whilst a deepening of the bed of the Elbe to the extent of about 40 centimètres is probable, the remaining part of the observed fall of the surface level is more likely to be due to a diminution of the discharge of the river, especially in summer. This conclusion is confirmed by an examination of the monthly averages from 1808 to 1857 and from 1858 to 1877, which show a lowering of level at Dresden of from only 45 centimètres in April to 72 centimètres in September.

W. C. U.

---

## *Regulation of the Rhone in the Canton of Valais.*

By Hr. Baurath Honsell.

(Allgemeine Bauzeitung, vol. xliii., p. 61.)

The Rhone, from Brieg to the Lake of Geneva, a distance of 75 miles, is a mountain stream, the bed of which lies mostly in the movable alluvial deposits of a broad valley. Many torrents fall into the Rhone at this part of its course, and during heavy rains or when the snow is melting the river becomes an impetuous rush of waters, charged with sedimentary matter and fragments of rock, which have in some parts filled up the bed of the stream, causing flooding of the valley.

The fatal flood of 1860 caused the authorities of the canton to

appeal to the Diet for funds to enable them to cope effectually with the evil; and Chief Engineer Hartmann, of St. Gall, and Engineer Blotnitzky, of Geneva, were ordered to make a thorough and technical examination of the matter. Their report showed that the proposals that had been made by the Valais engineers for the regulation of the main river and its tributaries were on the whole correct. The cost of the necessary works was estimated at about £240,000. The Council of State of Valais, fearing that this amount would not suffice for the entire works, caused another complete estimate to be made by the cantonal engineers MM. Venetz and Chappex, who put the total cost at £316,000. The matter was again referred to the Diet, and it was decided that the canton was to be assisted with one-third of the amount—in round numbers £105,600.

The system adopted for the regulation of the Rhone, in Valais, was a continuous dam, parallel with the axis of the current, and with spurs of various lengths placed at right angles. The protecting dike on the banks is of the usual kind, formed of gravel and sand, 14 feet 9 inches wide at the top, standing above high-water mark, and sloping 1 to 1½ towards the river, and 1 to 1 towards the land. The spurs are constructed of dry masonry, laid on a foundation of fascines, and surmounted with an upright course of quarry-stone. The facing of the spur slopes towards the river at an angle of 1 to 5, reaches to the height of ordinary low water, and ends in a broad circular buttress, originally formed of a loose heap of stones on a bed of fascines and surrounded by piles. Later on, when the new river bed had been formed, this buttress was constructed of cut stones, and the dyke shaped into regular form. To the spur heads wing dams are joined, running parallel with the axis of the river to about half the intermediate space between two spurs. These wing dams were built up to a little above low water, and were used only for some parts of the river; for instance, at hollow bends and opposite the discharge of affluents. In upper Valais the length of the spurs is 60 to 70 feet, the breadth of the stream at low water being from 98 to 118 feet, and at high water from 216 to 256 feet. In lower Valais the length of the spurs is 69 to 88 feet, breadth of low-water bed 118 to 137 feet, the width of the river between the dams 255 to 315 feet. The system has been in operation during the last ten or twelve years. The profile of the river bed approaches a parabolic form. Regulation has not yet been applied between Leuk and Siders. The spaces between the dams are already partly filled with pebbles and quicksand, which is being reclaimed, so that the perishable material of the foundations of the dykes and the paving of the dams are safe from injury. When the longitudinal and transverse sections of the river bed correspond with the direction of the new and shorter course of the current, the embankments will only require a small sum for maintenance.

The cost of the work for one bank was 40 to 42 francs per lineal mètre under ordinary circumstances. The remainder of the work

for the regulation of the Rhone differs but little from the usual constructions for the purpose. Irrigation and drainage works are also in progress. By introducing the muddy water of the Rhone over the low grounds and swamps, it is hoped that they will be raised. For this purpose outlet sluices have been made at suitable points in the dykes. These sluices were at first entirely of wood, but they are now strongly constructed of stone and iron. In order, however, to render these low-lying grounds fit for cultivation, an extensive system of canals and drainage has been commenced. The project includes the division of the Rhone valley from Brieg to the Lake of Geneva into eight great basins. The cost of the drainage canals is estimated at £53,400.

In August 1877, the waters of the Rhone rose to an unusual height. It has therefore been found necessary to make the dykes higher, both along the Rhone as well as the affluents, so that a further sum of £18,530 will be needed. The entire cost therefore of the regulation of the Rhone will be as follows—

| | Francs. | |
|---|---|---|
| 1. Cost as calculated in 1863 | 7,906,000 | |
| 2. Additional expenses as calculated in 1876 | 567,700 | |
| 3. Additional expenses for raising height of dykes | 463,000 | |
| 4. Drainage canals | 1,344,500 | |
| Total | 10,281,200 | say £411,248. |

J. J. W.

---

## *The Regulation of the Rivers Brenta and Bacchiglione, according to the Plans of the Engineers Fossombroni and Paleocapa.*

By Engineer-in-Chief G. Ponti.

(Giornale del Genio civile, an. xvi., pp. 341, 397.)

The decay into which the rivers of the Paduan district had fallen in the latter part of the last century attracted the attention of the Venetian Government. The Brenta, and other minor rivers, which had been turned from their natural course into the lagoon, by the frequent rupture of their banks, caused much damage to the adjoining country. Numerous plans for relief were proposed; and in 1787 the "Water Magistrate" entrusted the choice of the best to the advocate Artico. No plan, however, was sanctioned by the Senate, political and military events interfering with the prosecution of public works. In 1807 the Emperor Napoleon approved the plan of Signor Artico, but all that was done in this respect under the French kingdom of Italy was a slight cutting at Vigodarzere.

The Venetian provinces having fallen under the dominion of Austria, the great flood of 1816 induced the Government to take in hand the new cut from Fossalovara to Corte, which had been

proposed by Artico. The works were soon suspended; but the disastrous floods of 1825 and 1827 drove the Government to request the Grand Duke of Tuscany to afford them the advice of his venerable minister, Count Fossombroni. Unable, in consequence of his great age and many occupations, to visit the spot, Fossombroni called Paleocapa to his aid. Their final recommendations were drawn up under the title "Considerations on the Hydraulic System of the Venetian Provinces."

The plan recommended, and named after Fossombroni, was simple. It consisted in shortening as much as possible the course of the Brenta, by cuttings, of which the chief was that from Piovego to Corte, and reopening the discharge into the lagoon of Chioggia, where it was hoped that it would have no ill effect on the principal port, Malamocco. A new channel was to be formed for the Bacchiglione, outside of Padua, providing for the independent discharge of its floods; and gates and other works supplied to the existing canals were to render them independent of floods, and fit for navigation at all seasons. Two works of importance were included in the design—one where the Piovego canal crosses the Brenta, the other in the Bacchiglione at Bassanello, in order to divert the flood water. The navigation from Padua to Venice was to be restored to its former route; and care was to be taken to supply water from fresh sources to the canals to the left of the Brenta.

In 1840, that portion of Fossombroni's plan which encountered the most opposition, namely, the readmission of the Brenta into the lagoon of Chioggia, was carried out. But Paleocapa, then made Director of Public Works in the Venetian provinces, had the utmost difficulty in obtaining from the Government funds for the prosecution of the rectification of the two rivers, a work which was estimated at £231,600, exclusive of the works to the left of the Sile. An attempt was made to distinguish between works of utility and those of absolute necessity. For the latter it was proposed to lay out £184,000, divided over ten years. Details are given in the Paper at considerable length, of the various works proposed, which, however, it requires the aid of a plan on a scale of some magnitude fully to comprehend.

From a survey executed in 1867, when compared with that made by Denaix, in 1811, of the whole of the Venetian lagoon, it became evident that in the twenty-seven years which had elapsed since the readmission of the Brenta into the lagoon the latter had lost 15,000,000 square yards of surface; and that the cubic quantity of materials thus deposited by the water of the river amounted to 35,780,000 cubic yards; or to 1,323,000 cubic yards per annum. And this did not include any deposit below the water which had not reached the surface of the lagoon.

The volume of the Brenta in flood was estimated by Paleocapa at 1,130 cubic yards for the upper portion, and for the trunk below the confluence of the Piovego at 1,222 cubic yards. The flood of 1863 in the new channel from Spa to Sandon was measured

at a volume of 1,270 cubic yards; that in the lower trunk at 1,184, and the flood of May 1858 at 1,341, cubic yards. It appeared that the new channels more rapidly reduced the floods, by allowing the escape of the water in greater volume. The actual measurements of the volume of the Brenta at Limina, at Stra, and in the lower channel, proved that the calculations of the diversions effected by the various new works were accurately made.

Details are given of the various works, by means of which the course of the Brenta from Padua to the sluice at Brondolo was reduced by 7,653 yards in length, that is to say, from 59,806 to 52,153 yards, or more than 12½ per cent. Comprising the Roncajette canal, from S. Massimo to Ca Nordio, 33,720 yards of bank on either side of the waterway were regulated. The inclinations of the new channel, varying from 0·36 to 0·51 per 1000, are given by Signor Ponti; and a table of the heights of the floods of October 1836 and May 1856, before the opening of the new channel of the Brenta, of those of 1858, 1859, 1860, and 1863, before the construction of the discharge at Bassanello, and of nine since that work was completed, are given as taken at eleven different fluviometers.

The minute description of the works undertaken for the regulation of the volumes of discharge, is followed by an equally detailed account of the works executed for the improvement of the navigation.

The cost of the works executed to the end of 1866, defrayed by the Austrian Government, was £338,692, of which about £70,000 only regarded the navigation, and the remainder was spent on the systematising the two rivers. From 1866 onwards, the Italian Goverment has defrayed a further charge of £100,764, for works both of systematising the discharge and of improving the navigation. The cost of occupation of land and technical supervision are not included in the above. In the twenty years from 1846 to 1866 the Austrian Government laid out an annual sum of £16,920 in the improvement of the Brenta and the Bacchiglione. From 1866 to 1876 the National Government has devoted an annual amount of above £10,040 to the completion of the river works.

To the above report is appended a detailed account of the works executed for the systematising of the rivers Brenta and Bacchiglione, and of their respective cost. It contains ninety-six distinct items, all arranged under six general heads. The total cost is, as before estimated, £439,456. The rapid increase of the alluvial deposit in the dead lagoon of Chioggia is admitted to require new plans and new works in order to save that maritime city from being surrounded with marsh instead of with water. And the safety of the district of Piove is now imperilled by the consequent stopping up of its existing outflow channels. It is urged by Signor Ponti that notwithstanding these grave evils the objects of protecting the upper districts from the danger of floods, and of facilitating the navigation of the Brenta and the Bacchiglione, have been attained by the plans of Messrs. Fossombroni and Paleocapa.

F. R. C.

## *Monograph on the Torrents on the Coast of the Ionian Sea between Reggio and Assi, in the province of Calabria Ultra.*

By the Engineer-in-Chief, CHEVALIER G. AMENDUNI.

(Giornale del Genio civile, an. xvi., p. 191.)

The slope of the Calabrian Apennines between Reggio and the torrent Assi, on the shore of the Ionian Sea, contains fifty-five hydrographic basins, covering an area of 440,000 acres; yet there are portions of the coast not comprehended in these outfall districts. These contain, in addition, thirty-seven distinct zones, covering nearly 40,000 acres, partly hilly, partly flat, which have independent outfalls. With the exception of a narrow strip on the coast, the whole of this area rises by successive elevations towards that crest of the Apennines which is occupied by Aspromonte.

The character of the streams is principally torrential. Their discharge into the sea was formerly unchecked, and some of them formed channels of from 500 to 1,000 yards in width. On the construction of the embankment, of 12 to 15 feet in height, which carries the railway, girder bridges were erected, with spaces considered sufficient to allow of the outflows. But between the action of the sea and that of the torrents many disasters have occurred.

Signor Amenduni enters into a detailed account of the physical, geological, and meteorological features of the country, and into the extraordinary difficulties which they oppose to the work of the engineer. Waterspouts form over the crest of the mountains, and the torrents of water disengaged from the clouds plough deep ravines in the soil of the hills. The violent and sudden changes of temperature hasten the disintegration of the rocks. One storm in 1871 was so violent that nineteen railway bridges, each constructed with iron girders, were destroyed or injured by the resulting flood.

The destruction of the woods on the hills, induced, it is said, by meteoric erosion (sub-aërial denudation), has been indicated as one main cause of the destructive gales of the Apennine storms. The disintegration of the rocks has been attended by the removal of their surface by the rain. The débris thus caused on the mountain-sides was furrowed into ravines in the depressions of the slopes, the roots of the trees were loosened, the vegetation gradually destroyed, and the carriage of the disintegrated material downwards gradually destroyed the cultivated land. The cause of these changes being permanent, the changes are still in course of progress.

Public attention in Europe has been called to this mischief. In France laws passed in 1860 and 1864 authorised an outlay of £60,000 a year for ten years for the replantation and protection of the mountains. In Italy a law was passed in 1874 compelling the communes to cultivate and plant their lands. The works

considered necessary in all descriptions of hydrographic basins are stated to be the following: (1) The construction of dams to restrain the main torrents, as well as their influents, in the mountain ravines. (2) The protection and walling of the feet of the precipitous slopes. (3) Dry stone walling on the most rapid descents. (4) Embanking and clearing the channels of the torrents in the lower part of their course. In addition to this it will be necessary to raise the level of the railway, to enlarge the openings of some of the bridges, and to protect the embankment in some places with a sea wall. The three categories—of the torrents that rush directly into the sea, of those that unite to form a larger torrent still directed seawards, and of those that fall into a valley running parallel with the coast—are severally examined, and the character of the works required for the rectification and control of each is minutely described. For those torrents which, as the Gerace, the Siderno, the Turbolo, and the Allaro, bring down a fertilising mud, it is proposed that the landed proprietors should bear the charge of their reduction to system. For those which discharge their waters separately into the sea, across the railway, for the 12 miles between Reggio and Capo delle Armi, it is proposed that a general association of proprietors, under the direction of the provincial chief, and aided by the State, should undertake the duty. And this is rendered the more urgent, from the fact that the safety of the city of Reggio itself is menaced by the two great torrents, the Calopinace and the Saint Agatha. The surveys necessary are to be undertaken by the Government.

A detailed estimate is added of the cost to be incurred in the systematising of twelve of the principal torrents, and of the division of the cost between the State, the railway company, the province, and private individuals. For the torrents delle Saline, di Amendola, di Bruzzano, and La Verde, the total cost, for the works in the lower part of their valleys alone, is set down at £136,740. The additional value of the land, due to the works, is estimated at a figure somewhat above the cost. For six other streams, partial or occasional works of control are estimated at £72,820, without any corresponding abatement.

F. R. C.

---

## *Improvement of the St. John's River, Florida.*

By Capt. J. B. EADS, M. Inst. C.E.

(Van Nostrand's Eclectic Engineering Magazine, vol. xviii., p. 489.)

The drainage area of the St. John's river is about 7,500 square miles, and the average rainfall for the last twenty-seven years equals 50·27 inches at Jacksonville, and about 60 inches over the more southern portions. The mean tidal oscillations at Fort George's Inlet, near the mouth of the river, are 5·40 feet, the

extreme range being 8·30 feet. The oscillations at Pilot Town, within the mouth of the river, and distant about 3 miles from the outer edge of the bar, are nearly 1 foot less; and the width of the river at low water immediately above Pilot Town is about 1,740 feet; its greatest depth at mean low tide being 36 feet, and its sectional area at low water 36,000 square feet.

A mile below Pilot Town the shores of the river gradually widen out to the sea. The southern bank, a bluff one, 25 or 30 feet high, trends off east-south-east, or nearly at right angles to its direction opposite Pilot Town; while the northern shore, a low, marshy one, after bending to north-north-east for about a mile, trends quickly round to the north, its low compact sandy beach receiving the full force of the waves of the Atlantic for a mile beyond, where the foreshore is broken by the Fort George Inlet.

The width of the river's discharge, measured along the outer 2-fathom contour of the bar crest, and at right angles to the outflowing current, is nearly 3 miles, and the shoals which occupy the fan-shaped area enclosed between this contour line and the expanding banks of the river, constitute the St. John's bar, covering an area nearly 3 square miles in extent.

The deep-water channels through the bar have at various times occupied almost every part of this area. At present the river reaches the sea through three well-defined channels, the Pelican, Middle, and South channels. The first lies nearly in the direction of the axis of the river volume where it leaves the plainly defined shores of the stream; the second is a branch of the third or south channel, which latter follows the coast closely till near its mouth, when it takes a bend to the east and enters the ocean.

At mean high tide there is about 10 feet of water on the South channel, and 9 feet on the Middle channel—these being the two deepest.

The material forming the bar, the same as that which forms the sand beaches to the north of the river's mouth, is very compact, and so firm as to endanger the hulls of vessels taking the bottom. Although thus firm, no material is more sensitive to any disturbance of the equilibrium of forces, which causes it to come to rest, than the sand comprising such bars.

The height and protrusion of the southern bank of the river into the sea, would indicate the presence of a current to the south during most of the year; for the general tendency of all silt or sediment-bearing streams entering the sea at right angles to prevailing sea currents is to have their mouths turned round towards such currents, as though opposed to them; and from the records of the meteorological signal service during the last five years it is found that during 7·2 months per annum on an average the wind was from the north or north-east.

As the St. John's carries but little sediment to the sea, its bar is of the kind known as drift-bars, in contradistinction to similar accumulations of alluvious deposit.

The average quantity of tidal water passing into and out of

this basin twice a day amounts to nearly 2,000,000,000 cubic feet. This would produce an average rate of current equal to 2 miles per hour through a channel having a cross section of 30,000 square feet, or a maximum current of 4 miles per hour. With such a tidal basin, even without the additional advantage of the river current, resulting from a large annual rainfall upon 7,500 square miles drained by it, the Author has no hesitation in recommending the application of parallel jetties at the mouth of the St. John's river, as a certain means of permanently deepening the channel through the bar at its mouth. If the jetties were applied to reduce the width of the inflowing waters, now nearly 3 miles wide, and they were caused to pass through a channel only three or four-tenths of a mile wide, the frictional resistance would be greatly decreased, and higher tidal oscillations would occur at Jacksonville.

The size of the river at Pilot Town immediately above the bar, where it is exceptionally narrow, furnishes more reliable means of determining the width and depth of channel that can be maintained across the bar, with the desired depth between parallel works, than any mathematical computation. At this point the currents maintain a section 1,740 feet in width, with a maximum depth of 36 feet, the area of the section at half-tide being 36,000 square feet. This maximum depth could not be secured at the sea ends of the jetties with the width found at this point, for the reason that, under the influence of the waves of the ocean, the bottom of the channel there would assume a flatter shape than in the river.

The width found at Pilot Town, say 1,700 feet, is sufficient to secure a judicious mean between the probable demands of commerce and an economic expenditure for construction and maintenance. This width will produce a reliable channel of at least 20 feet in depth at average flood tide; in fact, more probably the depth will be 23 or 24 feet through jetties placed at that width.

The total length of the parallel jetties proposed is about 3½ miles, and estimated to cost approximately £350,565.

The mattress foundations of the sea ends of the jetties are 250 feet wide, and a similar width is deemed necessary in the line of the south jetty where it crosses the South channel near the main shore. The general mode of construction should be similar to that used at South Pass, with a few slight modifications in materials.

J. C. I.

---

## *The South Pass Jetties, Mississippi River.*

By E. L. CORTHELL.

(Transactions of the American Society of Civil Engineers, 1878, p. 133.)

Three years ago, when the works were commenced, a vessel drawing 7 feet of water could with difficulty pass over the bar of mud and sand formed at the mouth of the South Pass; a uniform channel has now been cut through, of sufficient width and depth for the

passage of the largest vessels. At a distance of 1 mile above the passes the Mississippi is 8,000 feet in width, with an average depth of 30 feet, giving a sectional area of 240,000 feet. The flood discharge of the river is about 1,000,000 cubic feet per second, of which the following percentages are estimated by different authorities to be discharged by the respective passes; South-west Pass, 46 to 39; Pass à l'Outre or North-east Pass, 46 to 51; and South Pass, 8 to 10.

It is estimated that one-thousandth by volume of the discharge consists of sediment held in suspension, and that the total quantity of this matter annually carried into the gulf of Mexico amounts to 275,559,000 cubic yards. The South Pass consists of a natural channel 700 feet in width and 40 feet in depth, with a sectional area of about 23,000 square feet, with smooth banks, and presenting all the appearance of a ship canal. At the mouth of the pass the east bank disappears, and is replaced by a reef over which 3 feet of water flows; the west bank also recedes, and as the water now escapes laterally the channel commences to shoal. At $1\frac{3}{4}$ mile below the bar proper commences, extending for a further distance of 3,000 feet, and consisting of a nearly level plateau covered by a maximum depth of 9 feet of water at average flood tide. Before the commencement of the jetties the bar was advancing at an estimated rate of 100 feet per annum. The body of water flowing through South Pass having been sufficient to form and maintain during an indefinite period that channel, it was concluded that the same volume of water, if suitably confined and directed, would be capable of eroding and maintaining a similar channel through the bar. With this object the jetties were designed and commenced. The possibility was foreseen, that, on the completion of the works, which would virtually amount to a prolongation for $2\frac{1}{2}$ miles of the existing pass, a new bar might be formed at the same distance below as before; but it was confidently expected that the current would be sufficiently strong to carry the sediment well out into the gulf before it was deposited; while the salt water current along shore would be deflected and caused to pass under the fresh water issuing from the pass, thus eroding the gulf bottom. In the design of the works the following objects were sought: to place the jetties parallel to the outflowing current and at right angles to the shore currents along the face of the bar, and to remove them sufficiently far back from the current to ensure their safety, when a channel 30 feet in depth for a width of 350 feet, as required by Act of Congress, was formed. The width between the guide piles was fixed at 1,000 feet, leaving a clear width between the jetties of 930 feet; wing dams are carried out some distance into the channel at right angles, with the object of confining the deep water to the centre, inducing deposit along the face of the jetties and more rapidly eroding the bar: these may be removed when their objects are accomplished. The jetties are constructed of willow mattresses 100 feet in length, 2 feet in thickness, with a width varying from 40 feet at the foundation to 20 or 25 feet on the top. The mattresses are built on inclined timber slips at the

water's edge, of willows cut on the various swamps beside the river, and towed to the site of the works in barges. Strips of yellow pine, 2½ inches by 6 inches, are first laid down 5 feet apart at right angles to the timber ways, and joined up to lengths of 100 feet; thus nine lengths are required for a mattress 40 feet in width. Turned hickory pins are then driven and wedged into 1⅛ inch holes bored in these at spaces of 5 feet. The willows are first laid transverse to the strips for a depth of 6 inches, then longitudinally for the same depth, and two more layers in the same way at right angles to each other. Cross-binders are next cut of the width of the mattress, with holes bored in them to fit the pins; these being then driven on, pressed down by levers, and secured by wedges driven in the ends of the pins, the whole is ready for launching.

When towed off the slip the mattress floats about 4 inches out of water; it is then taken to its place at the guide piles, and a layer of stone evenly distributed over it sinks it into place. The mattresses are thus successively piled on one another, the width being diminished from 40 feet at the bottom to 20 or 25 feet at the top, the whole of the batter being given to the side of the jetty facing the channel, as the back is found to silt up so rapidly that it may be made vertical without risk. The last mattress is pulled into place by a steam-piling engine, and the final layer of willows is built *in situ* and fastened down by cross-binders and pins driven into the binders of the last mattress. In order to hasten the confinement of the stream and to carry the work more rapidly seaward, the first mile of the east jetty and the first 3,000 feet of the west jetty were constructed of sheet piling on a foundation of mattresses, but this was subsequently finished off with permanent mattress work. Two rows, 12 feet apart, of 12 inches by 12 inches guide piles were driven at distances of 8 feet: 6 inches by 12 inches walings were bolted to the row on the channel side, and sheet-piling, 5 inches by 12 inches at the upper end and 3 inches by 12 inches at the lower, was driven 15 feet into the ground and spiked to the walings. The last 600 or 700 feet of the jetties is being constructed with a greater width of base than the rest, and with a batter on the sea face to enable them to resist the action of the waves.

The charts of soundings show that the depth of water between the jetties has increased 15 feet in the present shallowest part, that shoaling has taken place along the whole length of the back of the jetties, the water being 2 feet in depth where formerly it was 16 feet; while on the seaward side of the east jetty the land is a foot above average tides and covered with grass and weeds, where formerly the water was 16 feet in depth; and that the wing dams have caused a shoaling against the stream side of the jetties, protecting them from the scour of body of the current.

The wing dams are carried out into the channel at right angles to the jetties to a distance of 100 feet to 300 feet, and are considered temporary works, to be removed when of no further use. A row of guide piles is first driven, 20 feet apart, extending out into the

stream, and against these a row of foundation mattresses is sunk, 30 feet in width and 2 feet in thickness; across the end of this another mattress, 30 feet by 70 feet, is sunk to form an apron. A row of piles 8 feet apart is then driven through the foundation mattresses, about 12 feet from their down-stream edge, and bolted to a 9-inch by 12-inch waling 2 feet above high water. The wing dam mattresses, 2 feet in thickness and of sufficient width to extend from the foundation to 2 feet above the waling, are then raised on edge by the steam piling engine, and pinned against the row of piles by driving a row of piles 20 feet apart in front of them. The effect of some of these dams was very remarkable, causing much increase in the erosion of the channel, and in some cases a great irregularity of action during floods.

Next to the formation of the new channel through the bar the most important question was the effects on the depth to seaward of the jetties. It was anticipated that the greatest shoaling would probably occur in the Gulf during the progress of the works. In the three years occupied in the formation of the channel 3,000,000 cubic yards of sediment have been carried forward, in addition to that naturally held in suspension by the water; and moreover, until the completion of the channel the stream will not attain its maximum power of transporting sediment well out into the sea.

From a careful comparison of the soundings over an area of 178 acres immediately in front of the seaward end of the jetties in October 1877, with those taken over the same area in May 1875, it appears that shoaling has taken place over about $\frac{3}{7}$ths, and scour over $\frac{4}{7}$ths of that area; that the total scour has amounted to 335,572 cubic yards, equivalent to an increase of 2·1 feet in depth of the area subject to scour.

The works at the head of the passes are then described. The head of the South Pass was partially blocked by a bar giving only 15 feet of water over it, while a depth of 30 feet existed leading into the other passes. In order to increase the velocity of the currents into the South Pass for the purpose of eroding this bar, and at the same time to avoid loss of volume, which would retard the previously-described operations below the pass, it was decided to check to a small extent the flow down the other passes, and to conduct a portion of their volume into the South Pass. Mattress dams were first built confining the current to the pass, and by arms diverging from these it was sought to lead into it some of the volume that would otherwise flow to the other passes. These works, however, appear to have resulted in a loss rather than a gain of volume. From the upper end of these dams a single row of mattresses, 70 feet in length, 25 feet to 40 feet in width, and 2 feet thick, was then sunk, so as to form a submerged dam, 70 feet wide and 2 feet high, extending in a diagonal direction to the river banks. The results of these works are still in progress; the water has shoaled rapidly between the passes, the South-West Pass has itself shoaled to the extent of 1½ foot, while a much

increased scour is apparent at the head of South Pass, showing that the course of the river is now slowly adjusting itself in the desired manner. A. T. A.

---

NOTE.—The areas of scour and shoaling are given as 4,311,000 square feet and 3,459,000 square feet respectively, whereas from the table of areas from which this is deduced they would appear to be 5,345,000 square feet and 2,425,000 square feet respectively. Also average increase in depth over area scoured given as 2·102 feet should be 2·462 feet, or equivalent to an average increase of 1·166 feet over the entire area of 178 acres.—A. T. A.

---

## *On the Construction of the Narora Works, Head of the Lower Ganges Canal.* By Major H. H. JONES, R.E.

(Professional Papers on Indian Engineering, vol. vii., p. 227.)

The Lower Ganges Canal is intended to relieve the old Ganges Canal, constructed by Sir Proby Cautley, and opened in 1854, and also to extend the irrigation of the Ganges-Jamna Doab as far down as the Allahabad district.

After careful survey, the site for the headworks of the new canal was fixed at Narora, at which point the bed of the river consists of remarkably fine micaceous sand, totally unlike that of the Madras rivers, sinking when wet under the slightest pressure, and liable to be deeply scoured out in floods.

The works consist mainly of a weir, 3,800 feet in clear length between the abutments; and of a set of weir sluices 444 feet in length, standing in prolongation of the weir proper, and comprising forty-two openings of 7 feet 3 inches clear width, with piers 2 feet 9 inches thick.

At an angle of 105° with the crest line of the weir sluices stands the canal head, with its thirty sluices of 7 feet clear opening for regulating the supply; and at a distance of 751 feet up stream is the entrance to a lock, 150 feet long by 20 feet wide.

The water is designed to be raised 7 feet above its former cold weather level, and it is calculated that the obstruction caused by the weir will increase the highest floods 2 feet, or from 13 feet to 15 feet above low water. A minimum discharge of 1,630 cubic feet per second was registered in May 1873, and it is considered that a maximum discharge of 300,000 cubic feet may at some time have to be passed. The weir proper consists of a wall 8 feet thick at the base, 9 feet 9 inches high, standing on a line of blocks, or wells 10 feet square and about 10 feet deep filled in with concrete. The water falling over this wall descends upon a floor 40 feet wide and 5 feet thick, the down-stream edge of which is supported by a line of 8-feet circular wells, sunk to 20 feet below low-water mark, and having the intervals carefully piled. An apron and talus of heavy material complete the section. The weir sluices form a

double-storied building, standing on an ashlar floor 427 feet long by 155 feet wide, and 5 feet thick, enclosed all round by wells, and broken up by other lines of blocks into compartments of a size manageable for pumping and concreting.

Under the superstructure, the foundation is entirely composed of blocks or wells, 10 feet square and 12 feet deep, filled up solid, as are all the other wells, with concrete. It should be remarked that the wells under the weir proper, for a length of 500 feet measured from the sluices, are sunk to a depth of 30 feet, with the object of securing the weir against scour. This unusually great depth of foundation chiefly distinguishes the Narora Weir from the earlier works of a similar character on the great Madras rivers.

When wet, the white sand of the Ganges is practically fluid, and it is somewhat remarkable, therefore, that in sinking the wells the calculated displacement of the well, and the cubic content of sand thrown out, should be almost exactly equal. To prevent this sand from passing between the wells, close piling had to be employed. As the deep wells could be sunk only approximately vertical, the piling made but an indifferent joint; and moreover, a load of from 100 to 200 tons of rails had to be imposed upon each 8-feet well to force it down. It is suggested by the Author that iron caissons, sunk on the European plan, would have offered many advantages had they been obtainable.

The weir was begun in March 1873, and the end of the working season of 1877 saw it practically completed. As regards the masonry works, what remained to be done could be carried on leisurely during the rains, the work being far above the level of the highest floods; whilst the completion of the weir wall could be effected in the cold weather without difficulty, as the weir sluices will then entirely pass the supply of the river.

In designing the wrought-iron gates for the weir sluices and canal head, great care was taken to provide against their being set fast by silt lodging in front of them. Friction rollers are placed at the back of the gates, and the principle of an "inclined face" is applied to diminish the effort required to open them. The cost of the weir and headworks is stated to have been about 3,300,000 Rs., say £300,000.

B. B.

---

## *The Harbour Works at Flushing.*

(Deutsche Bauzeitung, 1878, pp. 281, 293.)

During the last few years the Flushing harbour works have undergone great improvements, and various extensions of the present works are in contemplation. The entrance to the harbour is between two piers built on a foundation of fascines faced with large rough stones, and protected on the inside by three rows of

piles driven with a batter towards the back of the piers. The distance between the pier heads is about 525 feet. The range of tide is about 11 feet 10 inches, the depth of water being 33 feet 9 inches at ordinary high water, and 22 feet at ordinary low water. Besides the old locks leading from the outer harbour to the inner dock basins, there are two new entrances side by side. Each of these new locks is provided with 4 pairs of reverse gates, to suit either high or low water. The following are the principal dimensions of the large lock: Length between the inner gates 479 feet, width 65 feet 7 inches, depth on the sill 14 feet 9 inches at ordinary low water, and 26 feet 7 inches at ordinary high water. The gates are of iron, and those shut against high water are 37 feet 5 inches high, and weigh about 70 tons each. The small lock is 26 feet 3 inches wide, 197 feet long between the inner gates, with 15 feet on the sill at high water, and about 18 inches at low water. These gates are of timber sheathed with copper as a protection against the worm. For the same purpose large flat-headed iron nails are employed on these works to protect fenders and other timber work. The floors of the locks are not built of masonry, but merely paved with stones.

A 65½-feet entrance leads from the inner harbour to the Middelburg canal. The gates are of timber, and their upper edge is only 18 inches above the ordinary level of water in the inner basins; so that in case of an unusual quantity of water in the dock, it would flow over the tops of the gates into the canal, which as a rule is at a lower level.

There are, in all, 26 pairs of lock gates at Flushing, so that it has become necessary to fit up a small dock entirely devoted to their repair. A gate that requires overhauling is floated into this dock over a sort of timber gridiron which is about 3 feet below the usual surface of the water. The dock gates being now closed, water is drawn off by an underground culvert, leaving the gate ready for the workmen. The area of the old dock basins is about 5½ acres, and that of the new basins a little more than 76 acres, making a present total area of 81¾ acres, with an average depth of 27 feet. At present there is a quay frontage round the new basins of only about 1,858 yards, the rest being pitched slopes. When the proposed dock extensions and quay walls are complete, there will be a total quay frontage of 8,744 yards. The quay walls are built on piles, the stone used being basalt. In the outer harbour, opposite the railway station, is a pontoon landing-stage, built at a cost of £28,500. It somewhat resembles the Prince's landing-stage at Liverpool. The platform measures 201 feet 9 inches by 82 feet, and is connected with the shore by an iron gangway.

G. J. C.

## *The Campana Graving Dock, Arsenal of Ferrol, Spain.*

(Memorial de Ingenieros y Revista Cientifico-Militar, March 1 and 15, 1878.)

The Spanish Government having recognised the necessity of constructing, at the arsenal of Ferrol, a graving dock adapted to the requirements of the Navy, Don Andres A. Comerma, Engineer of the Royal Spanish Navy, was entrusted in 1869 with the task of preparing the designs.

In consequence of the Civil War the works were not commenced until May 1873, since which time, with some few interruptions, they have been carried on more or less vigorously, and will be terminated during the present year.

The dock itself is built to admit, with the caisson in the first groove, vessels of a maximum length of 285 feet 5 inches; but the entrance is so constructed as to serve as a prolongation of the dock, with three additional grooves for the caisson, thus admitting vessels up to 420 feet in length. The end of the dock is circular, and the entrance is united to the quay walls by quarter cones in ashlar. The bottom is an inverted arch, with a slight fall towards the entrance for drainage. The sides are formed in steps, divided by three equidistant broad altars. At the end is an incline with lateral stairs, for the service of the workmen and materials; and on each side of the dock two similar ones. Along the bottom run longitudinally two channels for drainage, between which, and perpendicularly to them, are cut, at distances of 6 feet 7 inches, the recesses in which the keel blocks are placed.

The principal dimensions of the work are:

| — | Lengths. | Widths. | Depths. |
|---|---|---|---|
| | Ft. Ins. | Ft. Ins. | Ft. Ins. |
| At coping . . . . . | 475 9 | 88 7 | .. |
| „ bottom . . . . . | 429 10 | 52 6 | .. |
| From coping to bottom . | .. | .. | 39 4 |
| At H.W.M., O.S.T. . . | .. | 82 0 | 32 10 |
| „ mean tide . . . . | .. | 75 6 | 26 3 |
| „ L.W.M., O.S.T. . . | .. | 68 11 | 19 8 |

It is stated that this dock is therefore capable of holding the largest national or foreign vessels, that it can take them of larger draught of water than the one at Devonport, and that it is wider and deeper than the Matagorda Graving Dock lately constructed by Messrs. Lopez and Co. at Cadiz. The dock is built upon a layer of hydraulic concrete 3 feet $3\frac{3}{8}$ inches thick, on which comes an average thickness of 7 feet 7 inches of rubble masonry, supporting the invert of ashlar of an average thickness of 2 feet 4 inches. The side walls are 52 feet 6 inches in height, composed of rubble backing 6 feet 7 inches thick at the coping, and from 19 feet 8 inches to 26 feet 3 inches thick at the base, faced with ashlar also

averaging 2 feet 4 inches in thickness. These are the designed dimensions, but in many cases they have been exceeded on account of slips. The materials employed are all Spanish: the hydraulic lime from Guipuzcoa, the common lime from Asturias, the sand from pits near Ferrol, the quartz for the concrete from the shores of the bay, the granite for rubble masonry from the quarries of Monte Faro, and that for ashlar from those of Bustelo, about $3\frac{3}{4}$ miles from the work. The proportions of the mortar used were: for the bottom, 2 parts hydraulic lime to 1 part ordinary mortar; for the lower half of the work, equal parts of each; and for the upper half, 1 part hydraulic lime to 2 parts ordinary mortar, sea water being exclusively used for mixing. The excavation was first commenced at the inner end of the dock, but, on reaching the bottom, the quantity of water met with was so great that, added to the fact of the formation being argillaceous schist inclined at angles of from 25° to 40°, such considerable slips took place as to endanger, not alone the work itself, but even the neighbouring buildings of the arsenal. Slopes of $2\frac{1}{2}$ to 1 were insufficient to prevent the ground moving and opening at distances of more than 164 feet from the foot. It was therefore decided to utilise the work itself to support the ground by excavating and constructing the masonry in alternate lengths of from 13 to 20 feet, which should prevent slips while the intermediate lengths were being completed. Immense difficulties were, however, met with, and were greatly increased by exceptionally heavy rains. Timbering and piling seemed useless, for whole framings were moved from their places by the pressure of the earth. The bottom end of the dock was only got in and the walls carried up by working day and night, and filling the excavation, as fast as it was made, with concrete. The work was now proceeded with towards the entrances, the face of the excavation being constantly strutted from the masonry already constructed. The quantity of water met with in this part of the work was much less than at first, not exceeding 1,500 to 1,600 gallons per hour. At present there only remain to be completed the excavation and masonry of about one-half the length of dock entrance and the junctions with the existing quay walls of the arsenal. For this purpose a cofferdam has been constructed, elliptical in plan, about 295 feet in length by 23 feet thick and 36 feet in height.

Two centrifugal pumps, driven by an engine of 150 H.P., will empty the dock in three hours, lifting 660,000 gallons per hour. While pumping out the upper half the pumps will work together, discharging directly into the sea; and for the lower half the lift will be divided in two, one for each pump. In addition there will also be two small centrifugal pumps, driven by a 12-H.P. engine, for the purpose of keeping the dock dry when once emptied by the larger pumps. A complete system of culverts with all necessary sluice-gates, for running out the water to low water mark, for conducting it to the pump wells, and from the pump to the sea, and for refilling the dock, is built in the thickness of the side walls

and bottom of the dock. These culverts, lined with ashlar like the dock itself, are 5 feet 11 inches high and 3 feet 3⅜ inches and 4 feet 11 inches between the side walls. The pump wells, also lined with ashlar, are 9 feet 10 inches in diameter for the main pumps, and that for the auxiliary pumps is elliptical, 8 feet 2 inches by 4 feet 3 inches. The engine house will be built on a block of rubble masonry 82 feet long by 59 feet 1 inch wide, and 62 feet 4 inches deep, through which are pierced the pump wells, and culverts leading to them. The caisson is of wrought iron of the usual inverted peg-top form, weighing 308 tons when empty, and arranged to take in about 83 tons of water ballast.

The whole of the work has been carried out with the most minute care. All the ashlar has been finely worked, and no stones with the slightest defect, or even any difference in colour, have been allowed to be used. The granite is fine-grained, blue, and very hard.

For the concrete, quartz alone has been employed; and the rubble masonry has been composed of stones of from 7 to 28 cubic feet, well grouted in, and all the interstices filled with hydraulic concrete, so that when a small portion of the work was required to be demolished, powder and dynamite had to be resorted to.

T. A. G.

---

## *Lake Dam at Rappersweil, Zurich.*

(Die Eisenbahn, vol. ix., p. 85.)

This work has been constructed from the designs of Herr Schönholzer, in place of the timber pile-bridge erected in the years 1818–20, on the site of a structure dating from 1358. The dam, with its bridges for the navigation, stretches across Lake Zurich from the lower end of the Rappersweil railway station to the promontory of Hurden, the water width being 3,609 feet, and the depth varying from 10 to 2 feet. The upper surface of the dam is 35 feet 6 inches wide, and is divided longitudinally by an iron balustrading into three sections, of which one, 12 feet wide, carries a single line of railway; the central portion is the carriage-way, 15 feet 9 inches wide; and the remaining width of 7 feet 9 inches is for foot passengers. Of the total length of the dam, the first 575 feet constitutes the Rappersweil quay, which is also used for the extension of the railway station; then begins the Rappersweil bridge, 210 feet 6 inches long, and consisting of a 23-feet opening for small craft, and an iron pile structure of five spans of 29 feet 6 inches. At this point is a swing-bridge, with central pier 38 feet wide and two 43-feet-9-inches spans; then 187 feet 6 inches of iron pile bridge, in five spans as before, leads to the central dam, 1,411 feet long. This is followed by an iron pile bridge of ten 29-feet-6-inches spans and a 23-feet opening for river craft; and the structure ends with the Hurden dam 837 feet long.

The highest portion of the works is at the Hurden bridge, where the surface of the roadway is 8 feet 6 inches above the unusually high flood-level of June 1876; thence the dam declines towards Rappersweil at 1 in 40, and towards Hurden at 1 in 15½. The bed of the lake consists of an upper layer of sludge, under which occurs a bank of gravel sufficiently thick to form a good bearing when the foundations are distributed over a large area. Below the gravel, sludge again is found to an unknown depth, the substratum not having been reached by the longest piles driven. The walls of the Rappersweil quay are of masonry, resting on a foundation formed by three longitudinal balks supported on timber piles 20 to 26 feet long, driven in transverse rows of three piles each, 2 feet 8 inches apart. The space between the piles is filled in with dry stone, which extends outward from the masonry footings with a slope of 1 to 1. The filling of the dam is of gravel. Indications of lateral movement of the walls having been observed, the quantity of broken stone was increased to a height of 3 feet 3 inches above the masonry footings, having a breadth at top of 5 feet and a slope of 1 to 1. In the construction of the Hurden dam, piling was dispensed with, and instead broken stone was laid in up to low-water level, from which a dry wall with dressed stone facings was carried to a height of 5 feet 6 inches at a slope of 1 to 1, and thence to the dam top with a batter of 1 in 3. Settlement and slipping occurred (caused by the spreading of the foundation of broken stone), and necessitated the reconstruction of a length of about 100 feet, when the bearing of broken stone was largely extended. The masonry abutments and piers of the bridges are of ashlar set in hydraulic mortar, and rest upon piles, the heads of which are slightly beneath low-water level, surrounded by sheet piling, the sludge being replaced by concrete. The caissons of pile-bridges rest upon a staging supported by piles. The girders are of the ordinary plate type reduced to the least practicable depth.

The total cost of the new works, situated a little below the site of the former bridge, and including the section of railway from Rappersweil station through Hurden to Pfäffikon, amounted to £46,000 (of which sum the town of Rappersweil subscribed £36,640), distributed as follows:—

| | £. |
|---|---|
| Dam, roadway, footpath, and bridges between Rappersweil and Hurden as originally designed . . . . . | 36,000 |
| Increased expenditure due to amendment of the design . . . . . | 2,898 |
| Railway from Hurden to Pfäffikon . . . . | 7,102 |
| | 46,000 |

The swing bridge forms the subject of a separate article.

D. G.

## *Excavators and other Machines employed on the Danube Regulation Works, and on the Canal from Gand to Terneuzen.*

(Revue Industrielle, 1878, p. 337.)

The first excavator, designed by M. Couvreux, was built in 1861, and he used seven of these machines for excavating about 8,000,000 cubic yards on the Suez Canal Works. He has since used machines somewhat similar in character for the works on the Danube, and for the Gand and Terneuzen Canal. The excavator, built entirely of iron, has the general appearance of a locomotive, with an excavating apparatus resembling the buckets of a dredger. It is supported upon four axles, each having three wheels, two of the wheels being placed the ordinary gauge distance apart, and the third only 1 foot 8 inches from the central one, this wheel being taken off when the machine is to be conveyed along an ordinary line of railway. The excavator when in operation moves on three rails placed parallel to the direction of the cutting. An engine of 20-HP. works the excavating part of the machine, and another of 4-HP. propels the excavator. The chain of buckets projects from the side of the machine down the slope of the cutting, and its action along the slope resembles that of a huge plane. The angle of inclination of the row of buckets can be varied by means of a chain passing over a projecting jib and attached to the extremity of the frame carrying the buckets. The buckets have bottoms which open when the buckets reach a certain point, and discharge the contents into wagons running on a line of rails parallel to the road for the excavator. Thirty buckets, containing altogether $6\frac{2}{3}$ cubic yards, are discharged per minute; and allowing for stoppages, shunting of wagons, &c., about 3,100 cubic yards can, on an average, be excavated per day, but the amount depends on the material to be excavated.

Another machine was employed on the Gand and Terneuzen Canal for conveying sand and silt, dredged from the bottom, to a distance of nearly 60 yards, and to a height of 13 feet above the water-level.[1] This machine consists of a long tube projecting from the side of a floating dredger, and supported at the farther end by wire ropes passing over the jib of a crane fastened to the dredger. The tube has a downward inclination towards the shore of 1 in 20. The dredged material when raised falls into a receptacle into which a rapid stream of water is pumped, and the sand and silt are forced through the tube by the water and deposited where required on the banks. The weight of the tube is balanced on the opposite side of the dredger by the engine working the machinery and the pump for raising the water.

---

[1] A somewhat similar expedient was adopted by Sir John Hawkshaw on the Amsterdam ship canal. *Vide* Minutes of Proceedings Inst. C.E., vol. xxvi., p. 454. —Sec. Inst. C.E.

The amount of water mixed with the dredged material varies according to the nature of the material, but usually it consists of 3 parts of water to 1 part of sand.

A special machine (arrache-pieux) was devised for drawing out old piles from the bed of the Danube. It consists of a large crane erected on a pontoon formed of two boats placed side by side. By means of a winch worked by an 8-HP.-engine the chains fastened to the pile exert an upward pull of about 30 tons, which is sufficient to extract piles embedded 30 feet in the ground, and connected with portions of the structure below ground.

L. V. H.

---

## *Experiments on the Flow of Air through Orifices in a Thin Plate.*

By A. FLIEGNER.

(Civilingenieur, 1878, p. 401.)

This is a supplement to the Author's previous article on "The Flow of Air through well-rounded Orifices."[1] He has determined experimentally for six orifices of different size, *i.e.*, 3·17, 3·87, 5·11, 6·62, 8·68, and 11·36 millimètres diameter, the weight of air flowing through the same at various pressures, both inside and outside the air vessel. The orifices used were made in brass plates 12 millimètres (0·47 inch) in thickness, drilled cylindrically for about ½ millimètre, and then conically enlarged towards the outside at an angle of 45°. The results of the Author's observations are given in a tabular form. From these experiments he has, with the help of formulæ already given in his former article—and various assumptions the sufficiency of which he considers to be attested by the results—developed several new formulæ for the purpose of calculating with greater accuracy than with those hitherto employed, the weight of air flowing per unit of time through an orifice in a thin plate.

The Author adopts in the first instance the formula

$$G = a F p_m \sqrt{\frac{2g}{R T_m}\left(\frac{\kappa+\nu}{\kappa+1}\right)\psi} \quad . \quad . \quad . \quad . \quad (4)$$

where $$\psi = \left(\frac{p}{p_m}\right)^{\frac{2}{n}} - \left(\frac{p}{p_m}\right)^{\frac{n+1}{n}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$p$ being the pressure in the most contracted section of the outflowing air jet, $a$ the co-efficient of contraction, while the other letters have the same signification as in the previous article.

The influence of heat imparted from outside is neglected as being very small, in consequence of which $\nu = 0$, while it is assumed that the internal resistance offered to the outflow of the air as far

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. liii., p. 295.

as the section of greatest contraction is the same as for a well-rounded orifice; with the help of these suppositions the limits between which lies the value of the exponent $n$ may be determined; they are 1·37 and 1·41. The principal object of the Author's investigations is to determine the value of $\alpha$; this he finds to be variable, depending on the diameter of the orifice, and in a greater degree on the ratio of the external pressure to the internal $(p_o : p_m)$; these conclusions are arrived at by substituting the experimental values of the various quantities in the formula

$$\alpha = \frac{G}{F\,p_m}\sqrt{\frac{\kappa+1}{\kappa}\,\frac{R\,T_m}{2\,g\,\psi}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

which latter follows from the necessary modification and transformation of the formula (4) above stated.

The particles of fluid flowing from the orifice to the section of greatest contraction converge towards the axis of the jet, and in so doing follow certain curves. Assuming the orifice to be circular, the Author supposes a section of the jet made in a plane passing through its axis, and in this plane the trajectory (a curve intersecting each of the curves followed by the different particles in the plane at right angles) to be constructed, from one end of the diameter D of the orifice to the other. In consequence of their convergent direction the particles of fluid in a section through the jet, made on the surface formed by the rotation of the trajectory round the axis of the jet, have a component of velocity at right angles to that axis, and therefore a certain amount of *vis viva* in that direction; at the section of greatest contraction this has disappeared, having been spent in work, that is, transformed into pressure. By formulating this relationship between the *vis viva* in a given section, and the work done in the contraction of the jet, the Author arrives at a form of expression for $\alpha$; in order to do this he has assumed the trajectory to be a cycloid. Although this is subsequently shown not to be the correct form, the results obtained would have remained unaltered had another curve been assumed.

After further investigation as to the influence of the pressures on the co-efficient of contraction $\alpha$, the Author develops the following formulæ:

for $n = 1{\cdot}37$

$$\alpha = (1 - 2{\cdot}8860\,D)\,(0{\cdot}7880 + 0{\cdot}1390\cos\frac{p_o}{p_m}\pi) \quad . \quad (20)$$

for $n = 1{\cdot}41$

$$\alpha = (1 - 2{\cdot}8860\,D)\,(0{\cdot}7522 + 0{\cdot}1318\cos\frac{p_o}{p_m}\pi) \quad . \quad (21)$$

With the aid of these formulæ and those expressing the relationship between $\frac{p}{p_m}$ and $\frac{p_o}{p_m}$, which are—

for $n = 1{\cdot}37$

$$\frac{p}{p_m} = 0{\cdot}2820 + 0{\cdot}4891\frac{p_o}{p_m} + \sqrt{0{\cdot}0632 - 0{\cdot}2374\frac{p_o}{p_m} + 0{\cdot}2266\left(\frac{p_o}{p_m}\right)^2} \quad . \quad (18)$$

for $n = 1{\cdot}41$

$$\frac{p}{p_m} = 0{\cdot}2716 + 0{\cdot}4962\frac{p_o}{p_m} + \sqrt{0{\cdot}0650 - 0{\cdot}2435\frac{p_o}{p_m} + 0{\cdot}2333\left(\frac{p_o}{p_m}\right)^2} \quad . \quad (19)$$

the weight of air G flowing through the orifice in a second may be calculated from the formula (4) previously given ($\nu$ being 0).

As the calculations involved in the expression just stated are rather complex, the Author gives for practical purposes a more convenient formula (arrived at by purely empirical methods) for the weight of air flowing through an orifice, of the kind under investigation, in one second:

$$G_o' = (3465 - 10000\,D)\,F\sqrt{\frac{p_m^2 - p_o^2}{T_m}} \quad . \quad . \quad . \quad (24)$$

the weight $G_o$ being in kilogrammes, the pressures expressed in atmospheres of 10,000 kilogrammes per square mètre, and the dimensions in mètres.

This formula may be used for orifices varying in diameter from 3 to 12 millimètres (0·11 to 0·47 inch).

In the tabular statement of results to which reference has already been made, the ratio of the values calculated by the above formula to the corresponding ones obtained by experiment are given, showing a close agreement.

G. R. B.

---

*The Flow of Water in Pipes under Pressure.* By C. G. DARRACH.

(Transactions of the American Society of Civil Engineers, vol. vii., p. 114.)

In the well-known equation for the flow of water in pipes—

$$h'' = \frac{C\,L\,m\,v^2}{2\,g\,S} \text{ or } h'' = \frac{4\,m\,L\,v^2}{2\,g\,d} \text{ and } m = \frac{2\,g\,h''\,d}{4\,L\,v^2},$$

where $h''$ = friction head in feet;
$v$ = velocity of flow in feet per minute;
$g$ = 32 feet;
$m$ = co-efficient of flow;
$\frac{S}{C} = \frac{d}{4}$ = hydraulic mean radius in feet;
C = contour of pipe in feet;
S = sectional area;
L = length of pipe in feet;
$d$ = diameter of pipe in feet.

The value of "$m$" has been given by various experimenters for straight clean pipes of different diameters and for different velocities.

The following table, compiled from a series of tables deduced from experiments on the pumping mains of the Philadelphia Water-works, shows the effect produced by abrupt bends, check valves, and foul pipe; also the conditions under which, and the limits within which, the experiments were conducted by the Author:

FLOW of WATER UNDER PRESSURE. TABLE of EXPERIMENTS.

| Experiments. Number. | Diameter of Main in Inches. | Length of Pipe in Feet. | Number of Years Laid. | Static Head. | Friction Head. $H-h$. | Velocity. Feet per second. | "$m$." | REMARKS. |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 4,400 | 9 | 190·0 | 4·04 | 1·070 | ·03280 | Engine "Worthington," 5 per cent. deducted for slip, one curve of short radius, gauge on main outside check-valve. |
| | | | | | 9·24 | 2·285 | ·01609 | |
| 2 | 36 | 3,700 | 7 | 100·0 | 3·45 | 1·58 | ·01791 | Engine "Simpson," all curves 25 feet radius, no checks. |
| | | | | | 6·35 | 2·37 | ·01466 | |
| 3 | 20 | 4,320 | 11 | 3130·0 | 16·75 | 2·71 | ·01419 | Engine "Worthington," 5 per cent. deducted for slip, one quarter turn at basin. |
| | | | | | 39·84 | 5·11 | ·00941 | |
| 4 | 36 | 12,400 | 7 | 118·4 | 13·00 | 1·00 | ·05033 | Engine "Worthington," 5 per cent. deducted for slip, curves in pipes made with 25 feet radius, except at the basin, where 90° are made with a ⊤ pipe. |
| | | | | | 15·59 | 2·00 | ·01509 | |
| 5 | 30 | 20,200 | 2 | 167·3 | 6·27 | 1·47 | ·00575 | Engine "Cramp," 5 per cent. deducted for slip grade, undulating curves 25 feet radius, four check-valves on main, area of openings in deck 750 sq. in. Weight of four checks 1,280 lbs.; producing a pressure of 1·8 lb. per square inch or 4·16 head. This table gives the corrected frictional head. |
| | | | | | 21·86 | 3·23 | ·00415 | |
| 6 | 30 | 4,000 | new | 324·16 | 1·55 | 1·60 | ·00606 | Engine "Worthington," 5 per cent. deducted for slip, one quarter turn. All other turns made with curves 25 feet radius, &c. |
| | | | | | 2·68 | 2·14 | ·00590 | |

J. C. I.

## *The Potsdam Waterworks.*[1] By W. H. L. GREEN.

(Deutsche Bauzeitung, 1878, p. 425.)

The royal city of Potsdam, containing 44,614 inhabitants, is built on low land, partly sand, partly swamp, on the north bank of the Havel, and the shallow wells yield very bad water. In the autumn of 1874 the municipal authorities granted a concession, which resulted in the formation of an English company, for whom the works were designed and carried out by the Author. The concession provided that the water should be naturally or artificially filtered, and be supplied, at a constant pressure of at least 30 mètres above datum (90 feet[2] above average level of the streets, and considerably higher than any dwelling-house in the city), to every applicant within certain fixed limits, which include the city proper and the principal suburbs, together with the district on the south bank of the Havel, near the railway station. A moderately elevated plateau in the neighbourhood promised a good supply of water to deep wells sunk through the alluvium to the coarse sand below; and trial borings having been satisfactory, it was decided to adopt natural filtration.

The pumping-station buildings comprise a three-storied dwelling-house with office, a coal store, the boiler house (42 feet by 40 feet) for four boilers of which three are fixed, a tower 45 feet high for feed pump, condensers, hot and cold water cisterns, &c.; the chimney 106 feet high, and the engine house 58 feet by 43 feet, only half of which is at present in use. The water is taken from fourteen tubular wells, sunk in a line along the river bank, about 30 feet apart. Each well, when complete, consists of a 4-inch copper suction-pipe, 75 feet to 80 feet long, inside a cast-iron cylinder 40 feet long. A length of 10 feet of the bottom of the suction-tube is perforated with $\frac{1}{2}$-inch holes, in rows $\frac{1}{2}$ inch apart, between which 13 vertical hollow ribs, $\frac{1}{8}$ inch high, are soldered on. Three thicknesses of fine brass-wire gauze are wound over the ribs and soldered fast. The suction area of each tube is thus about 11 square feet; and as each tube yielded at the trial more than $1\frac{1}{4}$ gallon per second, the yield per square foot per minute is about $7\frac{1}{4}$ gallons. The water in the wells, when at rest, stands 4 or 5 inches above the level of the river close at hand.

The temperature of the water from the tubular wells rises about 48° Fahrenheit in winter to 56° in summer. An analysis by the official chemist, in June 1877, gave no traces of sulphuretted hydrogen, hydrosulphate of ammonia, sulphuret of calcium, or nitrous salts.

The boilers are cylindrical, 23 feet long, $5\frac{3}{4}$ feet in diameter, with two flues, each 1 foot 9 inches in diameter. Each boiler has

[1] Since this was in type an illustrated description of the works has appeared in the "Engineer" for Dec. 20, 1878.—SEC. INST. C.E.

[2] The measures given are in old German feet and inches, about 3 per cent. more than the corresponding English units.

510 square feet of heating surface. The engine, which is duplicated, is of the horizontal condensing type, with single cylinder, 20-inch diameter, and 36-inch stroke, fitted with Starke's self-acting expansion gear. A double-acting horizontal plunger pump is mounted close behind the steam cylinder, the plunger rod forming a continuation of the piston rod; the plunger is 12 inches in diameter, and works in two barrels placed end to end. The pump valves are of novel design, and are mounted horizontally. Each consists of the seat and four gun-metal rings (designed to afford the least resistance to the flow of water); these are of different diameters, and when at rest lie one on the other, the small one, which is closed at the top, being uppermost. The rings rise successively, and close in a similar manner, thus avoiding the concussion usually caused by the closing of high-pressure pump valves.

From the engine-house the water is forced through about 1,300 yards of 16-inch main to the reservoir on the Pfingstberg, at the foot of which a branch of the same size leads to the city. The reservoir is built half below and half above the natural surface, and is 97·5 feet square internally, and 16 feet deep, divided by seven parallel 20-inch walls (with arched openings) into eight vaults, arched in with two half-brick courses, the whole covered with 3 feet 3 inches of earth, sloped off 1½ to 1, and sown with grass. Proper ventilation is provided; and at one corner there is a door opening on to a small platform over the water, under which there is a float. Here an electro-magnetic telegraph apparatus is fixed, which constantly indicates in the engine-room the actual height of water in the reservoir. In front of the reservoir there is a valve chamber, 16 feet by 10 feet, and over this a tower 10 feet square and 50 feet high above the bottom of the reservoir, containing the standpipe. The water, on entering the chamber through the 16-inch main, passes over the bend of the stand-pipe (which can be raised 50 feet higher if necessary), between the two legs of which a backstop valve is fixed, constructed to admit of being raised like a sluice-valve, so that the stand-pipe can be put off duty when required, and the valve itself easily repaired, by taking it out through the top after removing the cover, without interrupting the flow of water in or out of the reservoir. Behind the stand-pipe the pressure main is connected to the 16-inch waste-pipe, which lies parallel to it, by a 16-inch branch and sluice-valve; and beyond this branch there is a sluice-valve on the pressure main, which then passes through the wall of the reservoir on a level with the paved bottom, which is 111 feet above datum. The overflow-pipe, 3 feet wide at top, is laid through the front wall over the pressure main, and passes through the valve chamber to the river. By means of these arrangements the reservoir can be conveniently emptied, shut off, and cleaned, without stopping the pressure supply to the city; while on the other hand the net cubic contents, 922,500 gallons, give about ten days' supply at the present rate of consumption. W. H. L. G.

## *Water Supply of American Cities.—Boston.*

(Engineering News, Chicago, 1878, p. 4 *et seq.*)

A history is given of the various endeavours made to obtain a good supply of water for the city of Boston. It was not till after long agitation on the subject that an Act was obtained, in 1846, by the City Corporation for procuring a supply of soft water from Lake Cochituate, formerly known as Long Pond. The works were completed in 1848. The lake is 3½ miles long, and its greatest breadth is about 1800 feet; it is divided into three sections by the roads crossing it, and thus forms a chain of natural subsiding reservoirs; when full it has an area of 801 acres, and a capacity of over 2,000,000,000 gallons. The water is conveyed from the lake to the Brookline reservoir in a brick conduit of an inverted egg-shape section, whose greatest inside width is 5 feet, and greatest height 6 feet 4 inches; its thickness is 8 inches, and the fall $3\frac{1}{16}$ inches per mile.

The conduit passes through two tunnels, made through porphyritic rock, 803 yards and 383 yards in length, respectively. The water is carried in four cast-iron pipes across Charles river, on a stone bridge with three arches of 30 feet span. Four stone waste-weirs serve both for letting off the water and for ventilation. The water is conveyed from the Brookline reservoir in iron pipes to the city. Boston is also supplied from the Chestnut Hill reservoir, a natural basin about 5½ miles from the city, having an area of 125 acres, and a capacity of 736,000,000 gallons; it is divided into two parts by a watertight dam. A dam had to be formed at the lower end of the basin for retaining the water; it is 2000 feet long, 20 feet wide on the top; the greatest width at the base is 150 feet, and the greatest height is 35 feet.

The Brookline receiving reservoir, of 22⅓ acres, is also formed from a natural basin by enclosing it on the northern side by a puddled embankment about 26 feet high. The mains are of cast iron. The service pipes from the mains to the houses are of lead, as it was found that the water from Lake Cochituate is not appreciably affected by contact with lead, whilst the wrought-iron pipes, which were at first adopted, soon became defective, and filled with rust.

The supply of water from the Mystic river, which was originally designed for supplying some suburbs of Boston, was incorporated into the general waterworks system in 1876. The daily consumption from this source, which in 1866 was under 1,000,000 gallons, reached over 8,000,000 gallons in 1876 and 1877, and with the existing reservoir space this appears to be as much as can be drawn off during a long drought. The purity of this supply being in danger of contamination from the sewage of towns and refuse of manufactories on the upper part of the river, a sewer has been constructed to convey the sewage and refuse into the river at a

point below Mystic lake, which forms the reservoir. The dam to confine the waters in the upper portion of the Mystic lake is 1500 feet long, and composed of earthwork, puddle, and concrete, with sheet piling in some places. Walnut Hill reservoir, which serves both for receiving and distributing, has a capacity, when full, of 26,000,000 gallons. The cost of the Mystic supply works up to 1871 was £278,700.

A new supply is to be obtained from the Sudbury river, the works for which are in course of construction; and as the discharge of the river is only moderate, and experiences considerable variations, three reservoirs are being made, having a capacity of 2,000,000,000 gallons. Several tunnels have been made for the passage of the water, and two bridges, one over Waban brook, 536 feet long, and the other over Charles river, 475 feet in length, the arch over the river itself having a span of 136 feet.

Descriptions of the various works relating to each source of supply are given in considerable detail in the article.

L. V. H.

---

## *Water Supply of Fall River, Massachusetts.*

(Engineering News, Chicago, 1878, p. 188.)

The supply of water for the City of Fall River is obtained from Watuppa lake, only 2 miles from the city; the lake is $7\frac{2}{3}$ miles long, and $1\frac{1}{2}$ mile across at its widest part; it is 3478 acres in extent, and has a watershed of about 20,000 acres. The average annual rainfall in that locality is $46\frac{1}{4}$ inches. The least rainfall between 1850 and 1875 was 37 inches, and the greatest $56\frac{1}{3}$ inches. The quantity of water required for supplying the city amounts to only one-thirteenth of the estimated yield of the lake. Owing to the absence of any dam for increasing the storage capacity of the lake, the discharge of water in dry seasons is insufficient for the requirements of the mills, but the waterworks have always been amply supplied. The average daily consumption per head is 26·28 gallons. The method of supply is that known as the stand-pipe system, and its economical working is attributed to the use of water meters. The construction of a reservoir for distribution is in contemplation. The water is pumped into the mains by two engines; a full description of which, and the results obtained from them, is given in the article. The distributing mains are of cast iron, and the service pipes of lead. The total cost of the works up to the end of 1875, was £283,940; and the annual cost of maintenance, including interest on the bonds, per 1000 gallons pumped, was 1*s.* $9\frac{1}{2}$*d.* in 1874, 1*s.* 4*d.* in 1875, 1*s.* $3\frac{1}{4}$*d.* in 1876, and only 1*s.* 1*d.* in 1877.

L. V. H.

---

## *The Quebec Waterworks.*

(Engineering News, Chicago, 1878, pp. 148, 156, 163.)

An account is given of the preliminary investigations, commenced in 1847, for the purpose of ascertaining the best source from which a supply of water could be obtained for Quebec, and the best means of conveying it to the city. In a report by Mr. Silliman, in 1848, the use of leaden pipes for distributing the water supply was deprecated, and it was urged that experience proved that water which had flowed through iron pipes was more readily contaminated by contact with lead, owing to chemical changes produced by the iron on the water and on the lead. Mr. Baldwin, who conducted the investigations, and reported on the subject in 1848, superintended the execution of the works in 1853. The supply is procured from the river and lake St. Charles, about 13 miles from the city. The area of the lake is about 2¼ square miles, and its watershed 112 square miles; its depth varies from 20 to 100 feet. The average annual rainfall is assumed to be about 30 inches. The fountain-head and subsiding reservoir and dam are about 8 miles from the city; the head is 486 feet above the level of high spring tides in the river St. Lawrence, consequently no pumping is necessary. The dam for enclosing the subsiding reservoir is formed of hydraulic masonry; it is 10 feet high and 200 feet long. The water is conveyed in an 18-inch cast-iron main, and the cast-iron distributing pipes are from 4 to 14 inches in diameter. The cost of the works up to the end of 1877 was £205,500, and the yearly cost of maintenance is £1,030. The water is supplied to forty thousand persons out of a population of fifty thousand, and the consumption is 75 gallons per head. The incrustation of the pipes with rust is not great, but it is sufficient to reduce the efficiency of the 4-inch pipes by nearly one half, so that several of the long small pipes will have to be replaced by larger ones. The Engineer of the waterworks, Mr. Bailliargé, who has supplied the foregoing statistics, points out the false economy of using small pipes; and he gives some interesting details about the waste of water and freezing of water in pipes.

L. V. H.

---

## *Railway across the Andes from Lima to Oroya.*[1]

(Le Monde de la Science et de l'Industrie, 1878, p. 145.)

The railway from Lima to Oroya, although only 105 miles in length, is among the boldest conceptions of modern engineering. Beginning at Callao, the port of Lima, the road traverses the Peruvian capital, and after following for some distance the banks of the Rio Rimac, abruptly enters the region of lofty mountains,

[1] An elaborately illustrated account of this railway, and of the Cerro de Pasca mines, is given in the 'Engineering and Mining Journal' (New York), for Dec. 21, 1878.

and ascends by a series of gradients, averaging 1 in 33, interspersed with sharp curves, to the summit tunnel of La Galera, 15,600 feet above the sea-level, or within 160 feet of the peak of Mont Blanc. In the first 97 miles there are fifty bridges and sixty-one tunnels. During the construction of the line great impediments were encountered, owing to the difficult nature of the ground, and the ill-feeling manifested by the native tribes at the encroachment into their country. The contractor had to import labour from Chili, and the workmen, not being acclimatised, were constantly disabled from sickness, and hundreds died of fever at Oroya; others were attacked by *soroche*, a disease common on the lofty plains of the Andes. All the materials were transported on the backs of mules, one thousand of them being employed, at a cost of £600 per day. In blasting rocks, &c., not less than 2,970 tons of dynamite were consumed. The cost of the line, which was designed and constructed by Mr. Meiggs, the well-known American contractor, amounted to £33,430 per mile. The original scheme contemplated a line to the Amazon, 250 miles farther on, with several branches, one of which was to the rich silver mines of Cerro de Pasca; but the financial difficulties of the Peruvian Government have necessitated a halt at Oroya.

G. G. A.

---

## *Conditions for the Establishment of Secondary Railways.*

Report by Messrs. Béral and De Basire.

(Revue générale des Chemins de Fer, 1878, p. 137.)

The Authors, having been commissioned by the French Minister of Public Works to study, in France and elsewhere, the economical conditions of construction and working of secondary railways (chemins de fer d'intérêt local), summarise their recommendations as follows:

*Gauge.*

1. Whenever it shall be necessary to construct special tracks, the normal gauge of 4 feet 8½ inches should, save in exceptional circumstances, be adopted.

2. On the other hand, whenever it is proposed to utilise existing roads, a width of 2 feet 6 inches (75 centimètres) between the rails is recommended, unless the nature of the traffic obliges the adoption of the normal gauge.

3. In cases where exceptional conditions render advisable the adoption of a narrow gauge on its own track, it is desirable that the gauge be not less than 1 mètre, which width is recommended as presenting the greatest advantages in respect of facility of working.

*Construction.* For lines of normal gauge—

1. The land should be bought for a single track. The average

requirements will not, as a rule, exceed 1 hectare 30 ares per kilomètre (say 5·13 acres per mile).

2. The width at formation level may be reduced to 13 feet for embankments of average height; and the same for cuttings—in the latter case exclusive of the width of the ditches.

3. The gradients should not exceed 1 in 40.

4. The radius of the curves may be as small as 150 mètres (492 feet), and in exceptional cases 120 mètres (393·7 feet). The speed must be lowered in passing these curves, as necessity requires.

5. The works of art to be for single track, and on the most reduced scale. The width between the parapets of under-bridges and viaducts, and between the abutments of over-bridges, should not exceed 13 feet. These works should be constructed of timber.

6. The width of the ballast at the top should be 9 feet, and its thickness 1 foot. As to its composition, the greatest latitude is allowable, provided always that the drainage of the track be well assured.

7. The weight of the rails should be: for iron, 44 lbs. to 50 lbs. per yard; for steel, 36 lbs. to 40 lbs. per yard.

8. The sleepers should be 7 feet 7 inches long, by 8½ inches to 10 inches wide, and 5 inches to 6 inches thick. They should be spaced 2 feet apart at the rail-joints, and 2 feet 9½ inches to 2 feet 11½ inches elsewhere.

9. The crossing places and sidings should not, as a rule, exceed 10 per cent. of the length of the line.

10. Fences should be entirely abolished along the line. Nevertheless, they may be used where their omission would be dangerous, or in the neighbourhood of inhabited places.

11. Level crossings may be open. Only for those of most traffic should be provided: (*a*) gates, with gatemen, or worked from a distance by signal; (*b*) safeguards of the nature of fixed signals, placed at a convenient distance, and providing for the stopping or slowing of the train.

12. The station buildings should comprise only the waiting-room, booking-office, and accommodation for the station-master. Retiring places should be annexed to each station. Shelters and platforms will not be provided, and the construction of quays, lairs, warehouses, &c., shall be deferred until the traffic renders them necessary. They shall then be built with materials procurable in the neighbourhood, of the least costly nature.

13. Distance signals will not be provided, but it will generally be convenient to establish a telegraph throughout the whole length of the line, exclusively for working.

14. Accessories, such as carriage sheds, water stations, and workshops, to be suitable to the restricted nature of the traffic.

15. The locomotives shall be six-coupled tank engines, and they shall be so designed that the weight on any one axle shall not exceed that on the axle of a fully-loaded goods wagon.

16. Passenger carriages shall be for two classes only. They

shall be for the most part composite, and may be of two storeys. All superfluous accommodation shall be excluded from their fittings.

The goods wagons shall be constructed according to the standard types of the principal lines.

The amount of the rolling stock will naturally vary with the length of the line and the character of the traffic. For a length of 30 kilomètres (18⅔ miles) three locomotives, seven to nine carriages, and thirty goods wagons, will generally suffice for a traffic of two or three trains daily in each direction, especially when wagons can on emergency be borrowed from the neighbouring principal line.

Under the above conditions the kilometric cost of a line, all expenses included, will vary from 60,000 to 90,000 francs, and will average 75,000 francs (say £4,800 per mile). Very complete preliminary studies, made with the greatest care both in the office and in the field, as well as a good and intelligent supervision of the work, are indispensable, in order to render possible the economy indicated without prejudicing the proper execution and the solidity of the works.

For mètre-gauge lines, laid on their own track, attention should above all be directed to the great economy which may result from the use of curves with radii as low as 80, and, exceptionally, of 60 mètres (262 feet and 197 feet); also to the divers economies which the adoption of this reduced gauge, and the employment of sharp curves, will allow of in the reduction of: (*a*) the width of formation level and of ballast; (*b*) average amount of land required; (*c*) cubic contents of the earthworks; (*d*) dimensions of the sleepers; and lastly (*e*) of the weight of the rolling stock—all of which items should be much less than when required for lines of normal gauge. The kilometric cost of such mètre-gauge lines on their own track will average 64,000 francs, and will vary, save in exceptional cases, between 40,000 and 80,000 francs (say £2,560 and £5,120 per mile). Finally, for lines laid on common roads, where the gradients may attain 1 in 20, and the radii of the curves be as small as 40 mètres (131¼ feet), with a width of 75 centimètres (2 feet 6 inches), the kilometric cost will average 40,000 francs, varying between 30,000 and 70,000 francs (say £1,920 and £4,480 per mile).

*Working.* For lines of normal gauge on their own track—

1. The train service shall be fixed at two, or at most three, departures daily in each direction, and may on certain lines be limited to one, excepting where it is necessary to add specials.

2. The ordinary trains shall be mixed, goods and passenger.

3. The average speed shall be 12½ to 13¾ miles per hour, including stoppages. The speed shall be relaxed in the sharpest curves and at level crossings, when signalled.

4. The time-tables shall be so arranged as to avoid as much as possible night service.

5. Distance signals shall not be used. The manual signals and

the ordinary head and tail lights shall be of the nature in use on the great lines.

6. The station staff shall ordinarily be composed of one station-master and one telegraph operator, who can besides be employed on the maintenance of the road. In stoppages all the service can be performed by a signalman.

7. The train *personnel* shall comprise one engine-man, one stoker, and one guard, who shall also act as ticket-clipper.

8. The passenger fares shall be for two classes only. They, as well as the goods rates, shall be specially regulated, as regards maxima, for each particular line, and having reference to the nature of the works, and the conditions of traffic, and the previous cost of carriage. They shall be in general higher than the tariff in actual use. The maximum weight of luggage allowed free to each passenger should be so regulated as to avoid as much as possible the work of weighing. Registration to be replaced by the delivery to each passenger of a number bearing the names of the two stations, and of which a duplicate can be attached to the package.

9. Clerking and the preparation of returns to be no more than strictly necessary.

10. Rents for the user and working of joint stations should be determined with regard to the importance of the traffic and the number of trains on each branch, and also to the advantages which may be expected to accrue to the principal line by the light railway acting as a feeder. Under such conditions, with low tariffs, and kilometric receipts up to 8,000 francs, it may be assumed, allowance being made for the annuity for maintenance of way and works, that the kilometric expenses D will be approximately represented, in terms of the kilometric receipts R, by the formula $D = 2{,}000 \text{ fr.} + 0{\cdot}33\ R$.

For narrow gauge lines, either on their own track or on common roads, the same dispositions may be applied; but for lines on common roads the effective speed must not, as a rule, exceed 15 kilomètres per hour. The proportion of kilometric receipts to expenditure would appear to differ but little from that indicated for normal gauge lines.

F. G. D.

---

## *On the Life of Rails.* By A. Funk.

(Zeitschrift für Baukunde, 1878, p. 25.)

For the purpose of testing them under similar conditions, the Cöln-Minden railway,[1] in 1864, laid 772 rails of seven different brands in the main line adjoining the Oberhausen station. The track is level and free from curves, but subject to the action of the train-brakes on account of its proximity to the station.

---

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xxv., p. 430.

Every day about one thousand five hundred axles pass over each track. To the end of 1877 the results were decidedly in favour of Bessemer steel rails. During the thirteen years there were removed, on account of breakage or wear—

| | | |
|---|---|---|
| Of fine grained iron rails . . . . | 80·7 | per cent. |
| „ "cemented iron" (Eiserne cementirte Schienen) . . . . | 68·0 | „ |
| „ puddled steel . . . . . | 33·3 | „ |
| „ Bessemer steel. . . . . only | 4·0 | „ |

of the respective numbers laid.

The wear of the Bessemer rails, which still remained in the tracks, averaged only 0·191 inch. From the recorded weights of the trains running over these tracks, it is calculated that 14,348,300 tons of gross rolling load produced a wear of only 0·1 inch, measured in the height of the cross section.

Since 1868 Bessemer rails have been laid to a greater extent, and at the end of 1876 there was a total length of 1054 miles laid with them, with the following results:

| | |
|---|---|
| Number of Bessemer rails laid . . . . . | 514,801 |
| Of these there were removed from the tracks: | |
| On account of breakage through the whole cross section . | 1,204 |
| „ „ „ fish-plate holes . . . | 227 |
| „ „ „ other faults . . . . | 504 |
| Together . . . . . | 1,935 |

or 0·376 per cent. of all the rails laid. The breakages prior to laying amounted to two hundred and fifty-one rails, or 0·049 per cent. of the total number.

The Rhenish Railway have deduced the following results for the wear produced by loads of 1,000,000 tons, run over Bessemer rails:

| | | |
|---|---|---|
| On level uncurved lines . . . . . | 0·0032 | square inch. |
| „ falling gradients of 1 in 100 . . . . . | 0·0173 | „ |
| „ „ „ 1 in 75 . . . . . | 0·0315 | „ |
| „ „ „ 1 in 38, with rail brakes (bremschlitten) . . | 0·0992 | „ |
| „ rising „ 1 in 38 . . . . . | 0·0126 | „ |

According to observations on the Austrian Southern Railway, a wear of 0·1 inch was produced—

| | | |
|---|---|---|
| In straight lines with gradients of 1 in 90 . . by | 9,674,500 | tons. |
| „ curves with rising gradients of 1 in 40 to 1 in 90, on outside rail . . . . . „ | 3,974,800 | „ |
| „ curves with rising gradients of 1 in 40 to 1 in 90, on inside rail . . . . . „ | 2,934,900 | „ |
| „ falling, on outside rail . . . . . „ | 5,514,800 | „ |
| „ „ inside „ . . . . . „ | 4,834,800 | „ |

of total rolling weights.

From these and other data, it is concluded that the life of rails

depends not only upon the traffic, but also upon brake-action and amount of curvature. To decide the exact amount due to each of these three elements, further observations are necessary. From present experience, the following figures may be deduced for Bessemer steel rails:

To produce a wear of 0·1 inch in height, the rail must be subjected to a gross train load of—

| | | | | |
|---|---|---|---|---|
| 25 | to 30 | millions of tons, | with light gradients and easy curves; |
| 15 | „ 20 | „ | „ | on average inclines with easy curves; |
| 10 | „ 12·5 | „ | „ | on gradients of 1 in 60 to 1 in 100 with average curves; |
| 2·5 | „ 7·5 | „ | „ | on gradients steeper than 1 in 60 with sharp curves. |

In estimating the life of rails from these data, due allowance has to be made for the greater amount of wear at stations, and for breakage.

F. R.

---

## *On Double-hook Couplings for Rolling Stock, as replacing Safety Chains.* By A. AGTHE.

(Die Eisenbahn, vol. ix., p. 121.)

The system here described is another form of the "reserve-couplings" used in Germany, as made by Steinhaus and others.[1] Every railway vehicle is provided at each end with a draw-hook, carrying a screw coupling and shackle; and to couple two together the shackle of one of them is thrown over the hook of the other and tightened up, while the shackle of the other is allowed to hang loose. As a reserve, in case of breakage, a "safety chain" is generally provided at each side of the draw-hook, carrying a hook at its end; and to complete the coupling the opposite safety chains are loosely hooked. These safety chains are expensive, troublesome, and of doubtful value; and hence it has been proposed to replace them, by using the loose shackle to form a reserve coupling.

The mode of effecting this, here described, is as follows. The draw-bar terminates, not in the usual rigid hook, but in a double eye; and a pin passed through this double eye carries outside the eyes a pair of links, and between the eyes a loose piece with a hook both above and below, resembling two draw-hooks set back to back, and welded together. The links carry at their outer end a nut, through which passes the ordinary right-and-left coupling screw; the farther end of this screw carries a similar nut, attached to a shackle. When two vehicles are to be coupled together, the shackle of one is thrown over the upper horn of the "double-hook" of the other, and tightened up; the double-hook of the first carriage

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. lii., p. 328.

is now hanging loose, and over its lower horn is hitched the shackle of the adjoining carriage, thus forming a second loose coupling, which will come into operation should the other give way.

The lower horn requires to be curved back farther than the upper, to prevent the possibility of the shackle dropping out. The hook is made throughout stronger than the coupling screw, so that if anything breaks it may be the latter, which can be readily replaced. Lastly, to provide against a fracture of the draw-bar, each end of the double-hook pin carries, outside the coupling link, a "safety link" attached to an eye-bolt, which passes through the headstock, and bears against the inside of it through the medium of an india-rubber spring.

Experiments made on the line from Zurich to Lucerne showed that the falling apart of the reserve-coupling never occurs in practice, and that the wear, after a run of 30,000 train-miles, was insignificant. Its advantages over safety chains are as follows:

(1.) In case of a breakage, a pair of safety chains give about 22 inches play before they come into operation, while the double-hook gives about $6\frac{1}{4}$ inches if the breakage is outside the underframe, and scarcely any whatever if it is inside. This of course makes an enormous difference in the strain brought upon the two systems.

(2.) The doing away with safety chains leaves more room between the vehicles for the man who couples up, and hence diminishes the chance of accident.

(3.) The double-hook system is simpler in construction, and cheaper to maintain.

W. R. B.

---

## *Theory of the Action of Railway Brakes.*

By E. PERRON.

(Organ für die Fortschritte des Eisenbahnwesens, 1878, p. 142.)

The Author first gives the equations for a heavy wheel moving forward on a rough horizontal plane, and at the same time turning round its axis with given angular velocity, and points out that if this given angular velocity be not originally such that the linear velocity of the periphery equals the horizontal velocity of the wheel (in other words, such that the wheel rolls on the plane) the effect of friction will speedily cause it to assume that particular value. He then takes the actual case of a railway vehicle acted on by a brake, and points out that the effect of the frictional resistance of the brake-block is to produce an equal and opposite frictional resistance between the rail and the wheel, and that it is this latter variable resistance which is the real external force tending to stop the vehicle; the brake-block friction must be treated as an internal

force. He then forms the ordinary equations for expressing the linear and angular acceleration of the wheel in terms of the applied forces, and from them deduces two expressions for $fX$, the frictional resistance between brake-block and wheel, one of them in terms of the time, the other in terms of the distance which is passed over by the wheel from the first application of the brake until it comes to rest (these expressions, however, assume that the co-efficient of friction between brake-block and wheel is always the same, and will require correction in order to take account of the fact now established, that this co-efficient varies with the speed, and is therefore never the same at any two moments during a stop). The expressions for X show that, when the wheel is stopping, the frictional resistance of the block is greater than that of the rail by an amount which is, in fact, the force expended at each moment in destroying the *vis viva* of rotation in the wheel. This excess, however, is insignificant, amounting, in the case of an ordinary railway wheel and axle, to about 20 lbs.

The maximum effect of a brake is attained when the rail friction which it calls into play is the utmost which the rail is capable of exerting, *i.e.*, is equal to the weight on the rail multiplied by the co-efficient of friction between rail and wheel. Any greater amount of brake friction can only be expended in stopping the rotation of the wheel, *i.e.*, in causing it to slide. The value of this maximum pressure is easily obtained from the general equations. The high value of this maximum appears to conflict with the well-known fact that even the heavily-loaded wheels of a tender can often be skidded by means of ordinary hand brakes, applied by a single man. This the Author considers to arise from two causes (1) the great mechanical advantage given by the screw gear of an ordinary hand brake, amounting to about 60 to 1; (2) the fact that the surface acted on between wheel and block is very much larger than that acted on between wheel and rail, and that according to Coulomb the total friction for a given pressure increases with the area.

The Author then goes on to consider continuous brakes, and lays down the five following essential requisites for a good brake:—

(1) Before everything else, simplicity of construction, combined with lightness and mobility in the parts, for rapid working.

(2) The brake to be controlled either by driver or guards.

(3) The action to be automatic, so that in case of accident the brakes shall put themselves on.

(4) The brake to be available even when the train is not completely made up.

(5) The working power to be always ready, and easily increased or diminished, so that it may be used for controlling the train in ordinary running, as well as for stopping it altogether.

The Author finally discusses the Heberlein brake, and observes that while it is seen at once to fulfil the first four conditions, it is otherwise with the last, since it seems impossible that a com-

paratively small friction roller should be able to produce the great pressure on the blocks requisite to elicit their maximum effect. He therefore gives a theoretical investigation to show that by varying the angle which the hanger of the friction roller makes with the horizontal, a strain of any required amount can be brought on the chains which actuate the brake-blocks.

W. R. B.

---

*On Continuous Brakes.* By C. SCHNEIDER.

(Zeitschrift des Vereines Deutscher Ingenieure, vol. xxii., p. 354.)

The Author glances at the history of brakes, from the ancient "shoe" or "skid" of road vehicles, through the various forms of lever and screw brake, to the continuous railway brake of the present day, necessitated by the increase in the traffic to be worked and in the weight and speed of the trains which work it. The increase of brake power thus required was first attempted to be attained by using heavier weights to force the blocks on the wheels; but the violent shocks which occur with this arrangement caused it to be abandoned in favour of the principle of applying the pressure by means of an elastic medium. Hence three systems of brakes, deriving their motive power from the following sources: (1) compressed air; (2) vacuum pressure; (3) water pressure.

The subject has been largely discussed, especially in England and America, and the chief forms of brake now in favour are accordingly described as under:

(1) *The Heberlein Brake*, chiefly used in Germany. This brake is worked by the *vis viva* of the train itself. On one of the axles are mounted two wooden friction rollers, and two corresponding rollers are carried on the free end of a lever, by moving which they can be brought up to or withdrawn from the former. Between them is mounted a chain wheel, on which is coiled a chain connected to the brake gear. A heavy weight acts through a system of links upon the other end of the lever of the friction rollers. When the brakes are not in use this weight is held up by a chain, worked by the guard or engine driver; but when the brakes are required, the chain is slackened, the weight falls, and, acting on the lever carrying the rollers, forces these into contact with the other rollers on the axle. The motion of the axle is thereby imparted to the former rollers, and to the chain wheel connected with them; the chain is wound upon the wheel, until it brings the brake-blocks into contact with the wheels; as the friction rollers on the lever shaft can then turn no farther they must slip, and the brake-blocks are then held in contact with the wheels by the tension of the chain, which is, of course, equal to the friction between the surfaces of the rollers. This brake can be very rapidly and effectively applied, but it is liable to cause severe shocks when put on suddenly.

(2) *The Smith Vacuum Brake.*—Here the pressure of the external air is applied by means of an india-rubber cylinder, collapsing endways (or, in the improved form, of an iron cylinder with a collapsable head). One of these is placed near each pair of wheels to be braked, and the collapsable end is connected to the brake-blocks by levers. The other end is in connection with a pipe running the whole length of the train, and terminating in an ejector placed on the locomotive. To apply the brakes, the driver turns the steam into the ejector, thereby exhausting the air from the pipe and the collapsable cylinders. The pressure of the external air then forces inwards the collapsable ends, and acts through the levers to force the brake-blocks against the wheels. The pressure is relaxed by opening a cock, which admits air into the pipe. Counterweights are provided for withdrawing the blocks from the wheels.

(3) *The Westinghouse Automatic Brake.*—In this case the pressure is obtained by means of an air pump on the engine, which compresses air in a main reservoir placed under the foot-plate. From this the compressed air is conveyed by pipes to an auxiliary reservoir under each carriage. From the latter it passes through an automatic valve (commonly called the "triple valve") to an air cylinder, and forces forward the piston, which is in communication with the brake-levers, and by its forward motion applies the brakes. Between the main reservoir and main pipe there is a three-way cock; and an automatic valve is fixed between the main pipe and auxiliary reservoir, as well as between the latter and the brake cylinder.

When the brake is ready for action, the three-way cock is so placed that the air can pass from the main reservoir through the main pipe to the auxiliary reservoir, and also to the brake cylinder. The triple valve is so arranged that any slight leakage in the auxiliary cylinder is always made up from the main pipe, while any sudden fall of pressure in the main pipe shuts the communication between it and the auxiliary reservoir completely. Thus in ordinary circumstances the pressure in the main pipe and the auxiliary cylinder is always equal; and as these are in communication with the two ends of the brake cylinder respectively, it follows that the pressure in both ends of the latter is the same, and therefore the piston is in equilibrium. But, if the brakes are to be applied, the three-way cock is turned so as to shut off the main pipe from the main reservoir and open it to the external air; the pressure in the main pipe is suddenly lowered, and the triple valve at once closes the communication between it and the auxiliary reservoir. The old pressure is still maintained in the auxiliary reservoir and behind the brake piston, while it falls to atmospheric pressure in the main pipe and in front of the brake piston; the equilibrium of the latter is thus destroyed, and it moves forward under the pressure behind it, thereby bringing the blocks against the wheels. It is clear that the same effect will be produced if the pressure in the main pipe be destroyed by any

other means, as by opening a cock in the rear van, or by the accidental breaking in two of the train. To take off the brakes, the three-way cock is turned, so as to shut off the main pipe from the outer air, and connect it with the main reservoir. At the same time the action of the triple valve shuts off the hind end of the brake cylinder from the auxiliary reservoir, and opens it to the outer air; the air behind the piston escapes, and at the same time the piston is forced backwards by means of a spiral spring, thereby withdrawing the blocks from the wheels.

(4) *Steel's Compressed-air Brake.*—In this brake the pressure is obtained, as in the Westinghouse brake, by means of an air pump and reservoir on the engine, and passes through a main pipe to an auxiliary reservoir and brake cylinder. The latter has one end in connection with the main pipe, and the other with the auxiliary reservoir; thus in ordinary working it has equal pressure on both sides of the piston, which, however, is kept at the end through which the piston-rod passes, because the total pressure on that side is diminished by the area of the rod. The brake is applied by opening the main pipe to the air; the pressure then falls, and at the same time a valve, opening inwards in the auxiliary reservoir, closes, and shuts it off from the main pipe. The piston in the brake cylinder is now unsupported in front, and is forced forward by the expansion of the compressed air within the auxiliary reservoir, thereby bringing the blocks against the wheels.

The above four brakes were those which were tried at Guntershausen in August 1877, and have since been reported on very fully by Herr Büte of Cassel. All gave favourable results; but which of them is to be preferred to the rest, can only be settled by a long course of practical experience.

W. R. B.

---

## *Self-Lubricating Hollow Axle for Mining Wagons, &c.*

By J. LIBERT.

(Revue universelle des Mines, vol. iii., 1878, p. 745.)

This plan of lubrication, which is the invention of M. Joseph Dessart, jun., of Herstal, is intended for wheels running loose on their axles, such as those of mining wagons; and has undergone numerous successful trials at various collieries in the neighbourhood of Liége. An axle of square section is used, hollow from end to end, the interior serving as a reservoir, which is filled with oil and closed by a plug screwed in at each end. Along the under-side of each journal, for about one-sixth of its circumference, is planed a flat face, in the middle of which is a vertical hole passing up into the oil reservoir. In this hole a screw is inserted, and in a small hole in the centre of this plays a very loose plug or pin. The jolting of the wagon in working makes the pin dance in the hole, thereby allowing air to penetrate into the oil reservoir, and

thus enabling the oil to ooze slowly out round the pin and lubricate the bearing continuously along its whole length. When the wagon is at rest, the lubricating action ceases, thus reducing the consumption of oil to a minimum. For replenishing the supply when required, the wagon is tipped over on its side, the end plugs in the axles are unscrewed, and the axles refilled with oil.

With trams or tubs holding about 7 or 8 cwt. of coal, and running on a road of 20 inches gauge, with wheels 9 inches in diameter, and journals 3 inches long and 1½ inch in diameter, the supply of about ¼ pint of oil contained in each axle has been found to last for twenty-eight days of twelve hours, the trams running about 1 mile per day, half the distance loaded and half empty; the oil costing about 1*s.* per gallon, the cost per tram has thus been only about ¾*d.* for twenty-eight days and 28 miles. The axles that have been examined after several months' working show no trace of wear, thereby proving their efficient lubrication.

A. B.

---

## *Fireless Locomotive for Tramways.* By M. Francq.

(Annales Industrielles, September 8, 1878, col. 315.)

At a recent meeting of the French Association for the Advancement of Science, M. Francq stated that in the tramway engines on his system, regularly employed on the Marly line, the reservoir, constructed of steel plates, holds 64 cubic feet of water, which may fall from a pressure of 15 atmospheres to that of 3 atmospheres. The steam is wiredrawn so as to enter the cylinder at a suitable pressure. The steam is exhausted into a tubular air-surface-condenser, which retains a part of the steam, and suppresses the noise of the exhaust. Theory, he argues, shows that the best performance is obtained when the steam is wiredrawn to a pressure of 3 or 4 atmospheres. Each pound of water, between 14 and 2 atmospheres, is capable of yielding a useful work of 5,900 foot pounds. The consumption of coal amounts to 5·81 lbs. per estimated HP. per hour. M. Francq estimates the daily cost of a fireless locomotive at about half the cost of an ordinary locomotive.

D. K. C.

---

## *Slow Combustion under Pressure.* By J. Henin.

(Revue universelle des Mines, vol. iii., 1878, p. 755.)

In M. J. F. Verdié's plan for burning in steam-boiler furnaces carbonaceous or non-bituminous coals, particularly those of poor quality, the chimney draught is replaced by the blast of a small blowing fan, the ashpit being closed in entirely; and the chimney damper is lowered so far as to maintain a constant plenum of pressure in the flues, amounting to about 1¼ inch to 2 inches column of water, while only a sufficient aperture is left for allowing the

burnt gases to escape into the chimney with a very low velocity and at very little above atmospheric pressure. Just before reaching the damper a portion of the burnt gas is led off, and mixed, while still hot, with the supply of fresh air delivered from the blowing fan; the bulk of air is thus increased sufficiently for producing the required velocity of current in the furnace and flues without increasing the quantity of oxygen supplied, the air delivered into the furnace no longer containing so large a volume of oxygen as the atmospheric proportion of 21 per cent. This diluted mixture entering the furnace through a row of small holes in the fire-bridge, just above the level of the fire, produces a slow and complete combustion of the coal on the grate, and no imperfectly consumed carbon in the form of carbonic oxide passes off into the flues.

This plan was applied in May last at the new pit of the Hasard and Valleresse colliery at Tamines (Belgium), and has been found to allow of utilising advantageously for steam purposes the small of the coal raised there from the lower seams of the Basse Sambre coal basin. The small coal burnt in this way is of a size that has passed through a grating of bars about $1\frac{3}{8}$ inch apart, and it has little enough of a free-burning character, and is very dirty, containing 18 to 20 per cent. of ash. When burnt in the ordinary manner with a strong chimney-draught, it gives scarcely any flame, the chimney temperature is from 650° to 750° Fahr., and the ashes and imperfectly burnt cinders amount to from 40 to 42 per cent., while the consumption per square foot of grate is but 5 to 6 lbs. per hour; consequently the evaporative duty in the best ordinary practice amounts to barely 4 lbs. of steam per lb. of coal, or only about 45 per cent. of the theoretical duty of 9 lbs. At the Hasard colliery by the new plan the consumption has been increased to 14 lbs. per square foot of grate per hour; the combustion is almost perfect, the quantity of ashes, clinkers, cinders, and coal in the ashpit having been reduced to only 24 per cent.; the evaporative duty is 7 lbs. of steam per lb. of coal, or nearly 80 per cent. of the theoretical duty; and the fire gives off flames 10 to 11 feet long, while the temperature of the waste heat escaping into the chimney is only about 250° Fahr.

A. B.

---

## *Purification of Greasy Water by Solution of Lime.*[1]

By MM. F. HÉTET and RISBEC.

(Bulletin de la Société d'Encouragement, 1878, p. 543.)

Experiments recently made by direction of the French Admiralty, upon the action of steam in contact with various lubricating oils, have confirmed M. Hétet's view that the saponification of the oils by the steam is the cause of the large proportion of fatty acid

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xliv., p. 284.

carried into the boilers of engines working with surface condensers. Samples of olive and colza oils being placed on flat plates in the steam space of a boiler working at 4½ atmospheres pressure, it was found that after several hours' exposure the proportion of acid, originally from 1·7 to 5·0 per cent. only, had increased to as much as from 45 to 54 per cent. Other experiments had previously shown that about five-sixths of the oil used for lubricating the pistons and slide-valves become acidified before leaving the surface condenser; and the remaining one-sixth becomes saponified in the boiler in the presence of oxide of iron, the whole forming the bulky, heavy, and very basic iron-soaps which constitute the scale that adheres so strongly to the boiler plates, and is thereby a source of so much danger.

In the lime method of purification—which consists in treating the greasy water with lime-water, whereby the fatty acids already formed are neutralised, while at the same time the fatty matters not yet acidified are saponified—the ultimate effect is that the greasy water so treated contains then only insoluble salts or soaps of lime, together with some free glycerine very largely diluted; none of which substances have any action either upon the iron boiler-plates or upon the copper or brass tubes, or any tendency to adhere to these metallic surfaces. The plan has already been applied, with suitable modifications in the arrangements, for the purification both of the feed-water obtained from surface condensers and of the distilled water intended for drinking or other purposes. In the case of feed-water, care is taken to ensure the reaction of the lime being entirely completed in the mixing apparatus, before the feed-water reaches the boiler, otherwise the metallic surfaces in the boiler would themselves come in for a share of the reaction; and the brass or copper tubes of the condenser are tinned on the steam side, as are also all copper pipes through which the feed-water has to pass prior to its purification being completely effected.

For obtaining the required supply of lime-water, ordinary slaked lime is dissolved in some of the already purified feed-water itself, thus avoiding the introduction of any additional quantity of water into the boiler. The proportion of lime theoretically needed, allowing for the impurity of the material in its commercial form, would be only one-eighth of the weight of the fatty matters employed for lubrication; but practically double this quantity, or one-fourth, should be used, in order to ensure an excess of lime for accelerating the reaction; and as 1 lb. of lime requires about 100 gallons of water to dissolve it, the above proportion is attained by a supply of about 25 gallons of lime-water per lb. of lubricating material.

For small engines, or where very little lubrication is required, the lime-water, prepared in any convenient vessel, is supplied at intervals into a cup, like the oil cups in ordinary use, having two cocks, by means of which the delivery into the feed-water is regulated so as to be nearly continuous; a similar plan is about to be applied on board various ships of the French navy. Where, however, the

lubrication is considerable, as is ordinarily the case, the lime-water is prepared continuously by mechanical means. A measured quantity of powdered lime is charged at regular intervals through a funnel into a closed mixing vessel; and into the same funnel a continuous stream of purified feed-water is delivered by a pump of variable stroke, adjustable at pleasure according to the quantity required; a second pump, of constant stroke, draws off the lime-water from the mixing vessel, and delivers it into the reaction vessel, which receives from the air-pumps the greasy feed-water to be purified. The capacity of the second lime-water pump being greater than the maximum capacity of the adjustable pump, more or less air is constantly drawn down through the funnel into the mixing vessel, which produces the agitation necessary to ensure a thorough mixture of the lime and water. This apparatus can be simplified by taking advantage of the condenser vacuum to dispense with the two lime-water pumps, and by employing the condenser itself as the reaction vessel. The plan having been previously applied to the engines of the French government cruiser 'Dupetit-Thouars,' its general application to all surface-condensing marine engines has now been ordered by the French Admiralty. The solid matter, consisting of calcareous soaps, introduced into the boiler by this process, remains in suspension in the water while boiling; it can without inconvenience be allowed to accumulate to the extent of 1 lb. per cubic foot of water in the boiler, or about 2 per cent. by weight, and thus entails no more frequent blowing-off or cleansing of the boiler than is ordinarily practised.

The same apparatus, with suitable slight modifications, is applicable to the purification of potable water, a filter of animal charcoal being added in that case. On board steamers using sea water in the boilers, or sailing-vessels furnished with stills, it is only requisite to prefix to the charcoal filter ordinarily employed an additional chamber for receiving the distilled water and mixing it with 1 per cent. of lime-water, prior to the filtration.

A. B.

---

## *Theory of the Injector.* By E. HERMANN.

(Zeitschrift des Oest. Ingenieur- und Architekten-Vereins, vol. XIX., p. 144.)

The Author considered it desirable to re-examine the theory, although Zeuner has already given the undoubtedly accurate thermodynamic equation applicable to the case. The investigation of the dynamical conditions is wanting in Zeuner, and Grashof's equation gives results differing by 75 per cent. from those obtained experimentally by Villiers. The units assumed are, kilogrammes, kilogrammes per square centimètre, mètres, and square mètres.

Let $M_1$ = weight of feed-water; M = weight of steam; $p_0$ = pressure in space from which steam is derived; $p_1$ = pressure in steam nozzle; $p_2$ = pressure in condensation space; $p_3$ = pressure

in space to be supplied (generally $p_3 = p_0$; but, on account of the weight of the back pressure valve, the greatest pressure in the delivery pipe is $\xi p_3$, where $\xi = 1{\cdot}05$); $p_4$ = pressure in space from which feed-water is derived. Generally $p_4 = 1{\cdot}03$ kilogramme per square centimètre.

When steady motion is arrived at, the pressure in the section of the steam nozzle is $p_1$. Then two cases must be distinguished. If $p_2$, the pressure in the condensation space, is less than $0{\cdot}577\,p_0$, then $p_1 = 0{\cdot}577\,p_0$. More rarely $p_2$ is greater than $0{\cdot}577\,p_0$, and then $p_1 = p_2$. Hence it will be seen that the Author proceeds on the assumption that immediately the pressure in the condensation space falls below $0{\cdot}577p_0$, the steam enters it with the velocity due to $0{\cdot}577p_0$ only. The theory is too complicated to be given. It leads to the general result that the ratio of the weight of the feed-water to that of the steam used is given by the equation—

$$\frac{M_1}{M} = \frac{\xi_1 w_1}{\sqrt{20\,g\,(\xi p_3 - p_2)}} - 1,$$

where $\xi_1$ is a co-efficient of correction, to allow for some small quantities neglected, and $w_1$ is the velocity of the steam in the nozzle. This has been ascertained in a previous investigation of the Author, and is given by the equation—

$$w_1 = \sqrt{\left\{\frac{2g}{J}\left(t_0 + \frac{p_0 v_0}{C\,(b+t)}\right) - \left(t_1 + \frac{p_1 v_1}{C\,(b+t_1}\right)\right.}$$

$t_0$, $p_0$, $v_0$ being the temperature, pressure, and volume, of a kilogramme of steam in the boiler, and $t$, $p$, $v$, the corresponding quantities at the steam nozzle, $C = 0{\cdot}1107$, and $b = 187{\cdot}2$ for steam. The greatest suction height at which the injector will work is found to be—

$$h_{max} = \frac{p_4 - p_2}{0{\cdot}102}.$$

The theory is then compared with the experiments of Yilliers, and the agreement is found to be satisfactory.

The Author also gives practical rules for designing an injector for given conditions of pressure and discharge.

W. C. U.

---

*The Korting Injector*[1] *as an Air-Blast.* By A. SCHEURER-KESTNER.

(Bulletin de la Société Industrielle de Mulhouse, 1878, p. 674.)

The Korting injector has been employed by the Author for two years for blowing and exhausting gases and vapours. It consists of a series of concentric truncated cones, one overlapping another, into the small end of which a jet of steam is delivered, and through

[1] *Vide* "Repertory of Arts," 1807, vol. iv. p. 171, for description of Nicholson's patent.

which the steam expands, and induces a current of air through the openings of the cones. The series of cones is enclosed in a cylindrical envelope, and the mixed current of gas and vapour escapes at the large end.

Experiments were made to test the action of a No. 2 injector. The consumption of steam was measured by the quantity of water evaporated in a boiler; and the quantity of air delivered was measured by one of Neumann's anemometers, which was placed within a tube 8 inches in diameter, and 3 feet 3 inches long, through which air was supplied to the injector. With a pressure of 4 atmospheres in the boiler, 706 lbs. of steam were consumed in forcing 17,532 cubic feet of air, at 77° Fahr., against a head of water of 6·56 feet, in 81 minutes. The temperature of the mixture of air and vapour was from 185° to 187° Fahr.; and that of the water through which it was forced, did not exceed 187° Fahr. Of the total quantity of steam consumed, 224 lbs. only, or about one-third, was condensed and remained in the water; the two other thirds passed away with the air. Reduced for the temperature 32° Fahr., the volumes of air and steam were respectively as 55 per cent. and 45 per cent., of that of the mixture. With a pressure of 5 atmospheres in the boiler, the quantity of steam consumed for the same duty was 17 per cent. less than at the lower pressure.

When the current of air was discharged freely into the atmosphere, the proportions of the mixture were, with a pressure of 5 atmospheres, 91½ per cent. of air, 8½ per cent. of steam. The temperature of the air was raised 16° Fahr. Evidently, the higher the initial pressure of steam, the less is the consumption proportionally. D. K. C.

---

## *Spur Fly-Wheels in the United States.*

By PROF. J. F. RADINGER.

(Dingler's Polytechnischer Journal, vol. ccxxix., p. 114.)

Spur fly-wheels are comparatively seldom used in the United States, belting being generally preferred, even for the transmission of a high power. But the specimens met with are often remarkably efficient, as will appear from the following particulars of three wheels inspected by the Author:

| | Corliss Exhibition Engine. | Asmokeag Mg. Comp. | Bay State Mill. |
|---|---|---|---|
| HP. transmitted | 1,400 | 570 | 400 |
| Diameter . . . feet | 30·0 | 28·0 | 20·5 |
| Revolutions per minute | 36 | 49 | 48 |
| Velocity of pitch-line per second, feet | 56·5 | 72·0 | 51·5 |
| Pressure at pitch-line . . . lbs. | 13,616 | 4,353 | 4,270 |
| Number of cogs | 216 | 204 | 192 |
| Pitch „ „ . . . inches | 5·23 | 5·18 | 4·02 |
| Breadth „ „ . . . „ | 24 | 18 | 18 |
| Pressure per inch of breadth . lbs. | 567 | 242 | 237 |
| Foot-pounds transmitted per second and per inch of breadth . . . | 32,083 | 17,416 | 12,222 |

To those conversant with the usual English as well as Continental practice, the high velocity of the wheels will appear striking. On this side the Atlantic the speed of wheels of this description hardly ever exceeds 30 feet per second at the pitch-line. In Sir W. Fairbairn's "Mills and Millwork," vol. ii., p. 101, 27·5 feet per second is given as a maximum. As an increase of this velocity means also an increase of wear and tear, in consequence of the larger number of the rubbing surfaces, it has been the practice, when increasing the speed, to diminish the pressure per inch of breadth by enlarging the breadth of the cogs. But wherever a correct shape of the cogs is to be obtained from the foundry, there will be a practical limit to this expedient. According to the Author's statement, the average relation between the pressure per inch of breadth $p$ (in lbs.) and the velocity per second of the pitch-line $v$ (in feet) is given by the formula—

$$p = \frac{11027}{6 \cdot 564 + v}.$$

The values of $p$ obtained by this formula are considerably lower than those of the above-cited American examples, even if no notice is taken of the wheel of the Exhibition engine, which appears to be rather exceptional in this respect. If, therefore, the American engineers are able to adopt these high velocities of circumference with safety, without resorting to the same reduction of the pressure per inch of breadth which has been found to be convenient here, the cause should be inquired into. The Author attributes it to the superior workmanship of the American wheels. Wheel-cutting machinery, by which an absolutely equal pitch and a correct shape of the cogs, independently from the breadth of the latter, are ensured, is largely used in the United States. The wheel is most carefully balanced, before and after the cogs have been finished. The use of shrinking rings is entirely discarded; everything is made true and tight by means of exactly-fitting bolts. Lastly, very careful attention is given to the foundations, which in some cases are specified entirely of ashlar stones, of a length equal to the radius of the wheel.

A. H.

---

*Casting of Chilled Gearing for Roll Trains.* By E. LADURON.

(Revue universelle des Mines, vol. iii., 1878, p. 742.)

In applying to the chilling of the gearing and pinions in rolling-mill trains Mr. F. R. Wheeldon's[1] plan for casting chilled rolls—the mould being constructed of cast iron for the parts of the casting intended to be chilled, and of sand for those not to be chilled—

[1] *Vide* "Mechanics' Magazine," 12 October, 1866, p. 229

one object to be aimed at is to prevent the chill from extending too deep, whereby the casting would be rendered brittle; if this be provided against, the chilled castings can be made of very strong and tough grey pig-iron. Another object, in casting shrouded pinions, is to enable the casting to free itself longitudinally from the chills during its contraction in cooling. The author describes a simple mode adopted for effecting both these objects, by constructing the chills in as many segments as there are teeth in the pinion, and proportioning the thickness of the cast-iron segments to the depth of chill desired, the moulding-box being rammed up with sand behind the segments. By also leaving gaps rammed up with sand between the chill segments, in the case of large pinions, and arranging these sand gaps to come opposite either the tops of the teeth or the bottoms of the intervening spaces, complete control is obtained over the extent of chilling produced. The segmental arrangement of the chills further facilitates the removal of the pinion from the mould after casting. For shrouded pinions, where the teeth alone and not the shields are required to be chilled, the chill segments are either shaped with a bevel at the ends of the teeth, so that, when the mould expands radially under the heat of the casting, the chill teeth are eased out longitudinally from between the shields sufficiently for preventing the casting itself from cracking as it contracts in cooling; or else, in the case of very long teeth, the chills are made not quite the full length of the teeth, and the deficiency in length is made up with sand in the moulding. A similar arrangement of segmental chills is applied for chilling the wobblers at either end of the pinion shaft; while the journals of the shaft are moulded in sand as usual, not requiring to be chilled.

Pinions of over 2 feet diameter, with the teeth chilled, have been in use for some years for the plate and flat-bar trains in the Couillet Company's rolling mills at Châtelineau (near Charleroi, Belgium). Here the rim, with a double set of chilled teeth, has been cast separately, and is wedged with oak keys upon an hexagonal shaft; this arrangement has proved very satisfactory in working.

A. B.

---

*On the Calculation of Pitch Chains.* By Professor K. KELLER.

(Zeitschrift des Oest. Ingenieur- und Architekten Vereins, vol. XXX., p. 169.)

In this Paper the Author investigates mathematically the tensional and bending stresses in the links and pins of pitch chains. Contrary to the opinions of previous writers on the subject, he supposes that the first tooth of the pitch-chain wheel takes two-thirds of the whole strain, and the second tooth the remaining third, as he thinks that in practical work the pitch is not accurate enough to utilise more than two teeth at a time.

The Author arrives at dimensions which are, in nearly every case, greater than those given in the published tables, notably those by Zobel and Neuberth, and by Neustadt. The Paper is accompanied by a table and scale-drawing, showing the correct dimensions for sixteen different sizes of chain, for loads varying from 2 cwt. to 30 tons.

W. P.

---

## *Explosion of the Flouring Mills at Minneapolis, Minnesota, May* 2, 1878.

By S. F. Peckham.

(American Journal of Science, vol. xvi., p. 301.)

The above explosion caused the destruction of six flouring-mills, the elevator, a machine-shop, blacksmith's shop, and planing-mill, with a number of empty and loaded cars, all being in flames within five minutes from the time the fire was first observed.

An examination of the ruins showed that the explosion originated in the Washburn A Mill, two more exploding successively; the other three did not explode, but were set on fire by burning flour carried through the broken windows. The Author remarks that it is significant that the three exploded mills were all running with open French purifiers, while the three that did not explode had been shut down several days; but he thinks that in *any* mill sufficient dust accumulates to form an explosive atmosphere if scattered abroad from any cause and ignited by flame. Experiments made before the coroner's jury showed that the proper mixture of flour and air only explodes when in contact with flame. White-hot wires and glowing charcoal only char the particles in contact with them.

The fire was supposed to have been caused by a set of stones running dry, which formed one of six sets, all discharging into a common spout leading to the dust-house, and all grinding middlings. A number of careful tests showed that flour ground from wheat that had been dried, and entered the stones at 100° Fahrenheit, produced flour at 130° Fahrenheit; while middlings leaves the stones at about 140° Fahrenheit, or about 10° hotter than if the stones were grinding dried wheat. In the Washburn A Mill two men at a time had the charge of the forty-two run of stone —a number, in the author's opinion, inadequate for that supervision necessary to guard against stones running dry. The Author concludes by remarking that the great practical and fundamental question for those interested in milling is, how to detect or prevent dry stones, particularly those used for grinding middlings; as though in 99 per cent. of cases only the stones are injured, the 1 per cent. is burdened with fearful possibilities.

W. P.

## *On Testing Machines for Iron and Steel.* By R. BREDT.

(Organ für die Fortschritte des Eisenbahnwesens, 1878, p. 138.)

The Author describes a testing machine of his own construction, several of which are at work with success. The piece to be tested is secured by suitable grips, differently arranged according to the nature of the test. One set of these is connected to one end of a system of levers, the other end of which is loaded by dead weights; the other set is connected to the lower end of an upright screw, the upper end of which passes through a fixed nut. The strain is put on by turning the nut, either by hand, or strap and pulley, and thus raising the screw, whilst the amount is registered by means of the dead weights. Elongations or deflections are measured directly by means of scales and verniers. Any apparatus for magnifying these small quantities and then measuring them on the magnified scales is objectionable, as inaccuracies are magnified in an equal degree.

Long experience has shown that the ultimate strength and elasticity of the same material appear to be different when different machines are used for testing them. For the same quality of sheet iron, and with an average of several specimens, the apparent difference in the strengths as tested by different machines has been found to be 10 to 15 per cent. Many engineers have recognised this fact, without attempting to assign the causes of it. The Author suggests the following:

(1) *Differences in the way of taking the Elongations, and in the duration of the Experiment.*—It is uncertain whether the ultimate strength of materials increases or decreases with the duration of the load; different materials may probably behave differently in this respect. At any rate the too rapid bringing on of the load is likely to produce shocks which tend to strain the material unequally, and vitiate the results. Where hydraulic pressure is used, the same evil is produced by the successive strokes of the pump, as may easily be seen by the rapid jumps of the pressure-gauge.

(2) *Differences in the form and mode of attachment of the Test Pieces.*—Short specimens always show a greater proportionate final elongation than long ones, because a considerable part of this elongation is always developed just in the neighbourhood of the place of breaking. Hence the length of the specimen tested is a point of the highest importance, and no descriptions of experiments which fail to record this are of much utility. Again, the piece should not be too broad in proportion to its thickness, as it is then impossible to equalise the strain over the whole surface. If the attachment is by bolts, these are apt to force their way into the metal, and thus bring the strain upon the outside fibres more than the middle ones; though this may be obviated by using larger bolts and wider ends to the test piece. If it is by wedges, these cannot be in close contact with the whole of an extended

surface of metal, and hence the strain is brought on at isolated points only.

The Author suggests that all the points to which he has drawn attention might be cleared up by an extensive series of experiments upon similar materials, but conducted with different testing machines, and with different forms and methods of adjustment for the test pieces. W. R. B.

---

## *On Piccard's Apparatus for Evaporating Brine without Fuel.*

By C. VON BALZBERG.

(Oest. Zeitschrift für Berg- und Hüttenwesen, xxvi., p. 469.)

This apparatus, constructed by Weibel Briquet and Co., of Geneva, is founded on the principle of the conversion of mechanical energy into heat by the agency of compressed steam, and its recovery by condensation. In the most complete form it consists of five separate parts:—1, A preliminary or brine feed heater; 2, an evaporating vessel proper; 3, a pair of exhausting and compressing pumps; 4, a condenser and brine super-heater; and 5, a regulator between the condensing and evaporating vessels. Each of these has separate and distinct functions; but as all are in communication by lines of pipes, the operation once started goes on continuously, the only fuel used being that required to fill the condenser with steam at two atmospheres pressure. The evaporating vessel is a cylindrical boiler about 16 feet long and 5 feet in diameter, with a shaft traversing it from end to end, carrying screw blades or paddles, which receive a slow rotatory motion, whereby the salt as it deposits is traversed toward a mud-hole at the lowest point, and passes out through a tube provided with two slide valves, forming a kind of steam-tight sluice; the upper one being opened until the space between it and the lower one is filled, when it is closed; and, the latter being opened, allows the salt to fall into a perforated drainer at the bottom of the collecting vessel, which is lifted out whenever it is filled. There are three circulating passages; the first, a small tube at one end, of the nature of a feed-pipe, which receives a supply of weak mine brine from the preliminary heater No. 1, at a temperature of nearly 100° C., the level being kept constant by a hydraulic head in the feed cistern; the second, a large pipe for the admission of super-heated brine from the condenser; and the third a steam dome and pipe leading the steam produced to the pumps. The latter are double-acting exhausting and compressing pumps, driven by a rotatory hydraulic motor of any kind. The condenser, or heating vessel, is a vertical boiler 10 feet high, and 5 feet in diameter, filled with vertical tubes like an ordinary upright tubular boiler, communicating with a water space above and below. The space within the shell, exterior to the tubes, forms the steam space in the condenser; the condensing medium, heated brine, circulating through the tubes from the lower to the upper water space. The condensed

water passes through the preliminary heater No. 1 by a similar system of circulating tubes, where it is finally deprived of nearly all its excess of sensible heat by the brine arriving at atmospheric temperature; the heated circulating brine, on the other hand, passes through the equaliser No. 5. This is a close cylindrical vessel, connected with both evaporater and condenser by ports which are alternately open and shut by a slide valve. This allows the communication to be made from one vessel to the other; but the levels being so arranged that the evaporating boiler is highest, the circulation can only be in one direction—that is, the overflow is always from the evaporater through the equaliser to the condenser. The heated brine returns through a special tube to the top of the evaporater at the end opposite to the steam dome.

In starting the apparatus, the evaporating boiler is filled to its proper level with weak brine, which, together with the condenser, is heated by blowing steam from a special boiler, at 2 atmospheres pressure, through them. When the right temperature is attained no further heat is required, the loss being made up by that developed in the compressing pumps.

The liquid in the evaporater being under atmospheric pressure, each unit of water evaporated produces an equal weight of steam, with 537 calories of latent, and 100 calories of sensible heat. This, when compressed by the pumps to about $\frac{1}{10}$ of its original volume, attains $2\frac{1}{2}$ atmospheres pressure; or, the unit of weight will now have 517 calories latent, and 128 calories of sensible heat. In the condenser this quantity is re-distributed into 108 calories, corresponding to the sensible temperature of the condensed water, and $517 + 128 - 108 = 537$ calories transmitted by the walls of the tubes to the circulating brine. The latter being admitted at the bottom of the condenser at boiling heat, 108° C., absorbs the available 537 calories, and arrives at the exit point with a total of 645 calories per unit; and as the vessel is hermetically closed, evaporation cannot take place except to a very small extent, and therefore the brine will be heated to 120° C., corresponding to the pressure of 2 atmospheres, and the remaining heat becomes latent.

The superheated brine returning under these conditions to the evaporater, where the pressure is only 1 atmosphere, must give rise to a rapid evolution of steam. Here it meets with an equal weight of original brine at 100° C., which, to be raised to the boiling point of 108° C., will absorb 8 cal., the remaining 637 cal. being sufficient to produce 1 kilogramme of steam of the normal pressure, which, passing to the pump or condenser, will continue the process so long as the necessary heat lost by transmission, radiation, &c., be supplied by the conversion of the mechanical work of the water-power into heat by the pumps.

According to the calculations based upon the late P. von Rittinger's theory of the steam pump, an apparatus capable of producing 1,000 tons of salt per year of three hundred working days would require nearly 31 HP. for driving the pumps, which agrees

with the inventor's experiments, which required 30 HP. for a similar production. The heating surface, supposing the difference of temperature between the compressed steam and the heated brine to be 12° C., is calculated at the rate of 3½ kilogrammes effective production per square mètre per hour; or, for the above production of 1,000 tons, 40 square mètres of condenser surface will be required. In a somewhat similar pan constructed by von Rittinger in 1857, at Ebensee, the effect varied from 2·3 to 3·35 kilogrammes per hour, but the heat was imperfectly utilised owing to the deposit of a thick coat of salt over the surface which considerably interfered with the transmission of heat. In the apparatus under consideration no deposit can actually take place to any extent, except in the evaporater, as the circulating brine, though at the full point of saturation at the commencement, becomes superheated in the condenser, and therefore capable of re-dissolving any deposit that may take place at first.

In another modification of the apparatus the compressing pumps are done away with, the initial heat being provided continuously by steam at 2 atmospheres pressure from a boiler, the exhaust steam being made to heat a second similar apparatus, the steam from that a third, and that from the third a fourth. This depends upon the principle developed by von Rittinger that in a closed evaporating vessel for equal heating surface the amount of water evaporated per unit of time depends, not upon the temperature of the heating steam but upon the difference between it and the temperature of the fluid to be heated; and when this is constant equal differences of temperature will correspond to equal quantities of salt deposited. If therefore the first apparatus be supplied with steam at 2 atmospheres or 120° C. temperature, and the exhaust of the last be passed through a condenser like that of a low-pressure steam engine, the waste water may be cooled to 40° C., or a range of 80° C. of heat will be available, which, divided over four sets of evaporaters, will give a specific difference of temperature in each of 20° C. According to the statements of the inventors, with a combination of four evaporaters 12 kilogrammes of salt, or with five 15 kilogrammes, may be produced with a consumption of 1 kilogramme of coal. The injection water required is 21 litres with a battery of four, or 17 litres with one of five evaporaters, or for an annual production of 4,000 tons of salt 12 cubic mètres of cold water per hour. The paper concludes with a comparison of the present with former apparatus in which steam was used in saltpans.

H. B.

---

## *Air-Compressors and Rock-Boring Machines.* By H. Mativa.

(Revue universelle des Mines, vol. iii., 1878, p. 652.)

During the latter part of 1877 a series of trials was made of Rock-Boring Machines at the collieries of Levant du Flénu, Cuesmes, Belgium, by the engineer to the collieries, M. Mativa, in

conjunction with four other Belgian mining engineers. At these collieries a powerful air-compressor had recently been erected from the designs of M. Cornet,[1] on the principles here investigated by M. Mativa, who briefly reviews and comments upon the chief systems of air-compressors hitherto in use, classing them as dry or wet, and pointing out the important advantages presented by the latter class in the injection of a finely-divided spray of cold water into the compressing cylinders, for counteracting the rise of temperature occasioned by the compression, and for preventing losses by leakage of air and by clearance.

The air-compressor at Levant du Flénu has a pair of vertical single-acting compressing cylinders, fixed over and worked direct by the piston-rods of a pair of steam cylinders, which are coupled at right angles by a crank-shaft carrying a 7-ton fly-wheel. The compressing cylinders of 23⅝ inches diameter are water-jacketed, and the steam cylinders of 17 inches diameter are steam-jacketed, with Meyer expansion gear variable by hand; the stroke is 3¼ feet, and the engines make thirty to forty revolutions per minute, compressing the air to 4 or 5 atmospheres total pressure. The compressing cylinders are open at the bottom, and the four inlet valves are in each compressing piston. These valves, and the four delivery valves in the top of each compressing cylinder, are of gun-metal, beating on gun-metal seats; they are all 5½ inches in diameter, the inlet valves weighing 8 lbs. each, and the delivery 7⅝ lbs. The cold water injected close to the top of each compressing cylinder is supplied through four horizontal gun-metal nozzles, each containing ninety holes of less than $\frac{1}{24}$ inch diameter; these holes are arranged in two circles of fifty and forty, and all converge towards the axis of the nozzle, delivering their minute jets against an inverted conical button, which thus distributes a very finely-divided spray into the cylinder. A force-pump, worked by an eccentric which is keyed on the fly-wheel shaft almost coincident with the crank, supplies the injection in the upstroke of the compressing piston during the compression and during the delivery of the air, the temperature of which is by these means brought down so as to be, on entering the receivers of 2,440 cubic feet capacity, only 13° Fahr. above that of the external atmosphere. The temperature of the atmosphere and of the injection water was 50°; the calculated quantity of water to prevent, at 4½ atmospheres total pressure, a rise of more than 13° was ·004 cubic foot per cubic foot of air at atmospheric pressure, while the quantity actually employed was ·0065. The indicator diagrams taken in trials of this air-compressor show its useful effect to be 85½ per cent. The beam-engine arrangement, however, adopted nearly thirty years ago at Govan Colliery, Glasgow,[2] with a vertical single-acting compressing cylinder on each side of the beam centre, is considered preferable by M. Mativa, on account of its simplicity and compactness.

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. xlix., p. 352.

[2] *Vide* Proceedings Institution of Mechanical Engineers, 1856, p. 145; and Revue universelle, 1st series, vol. i., 1857, pp. 302 and 505.

Nine different Rock-Boring Machines, which are described and criticised by M. Mativa, were sent to the colliery; numerous trials were made of three of these, namely those of Dubois and François, Dunn, and Schram; of the other six—namely those of Ferroux, Ingersoll, Sachs, Taverdon, Trautz, and Turrettini—some underwent only isolated trials, and others were merely exhibited. The following is a condensed summary of the trials made as to rapidity of boring horizontal holes in lower carboniferous limestone (from Soignies) with $3\frac{1}{2}$ and $2\frac{1}{2}$ atmospheres effective pressure, the diameters of the pistons in the machines being—Dubois and François, $3\frac{3}{8}$ inches; Dunn, 4 inches; and Schram, $3\frac{1}{4}$ inches:

| Effective Pressure. | Total Length Bored. | Rate of Boring per minute. | |
|---|---|---|---|
| | | Exclusive of changing Tool. | Inclusive of changing Tool. |
| $3\frac{1}{2}$ atmospheres. | Inches. | Inches. | Inches. |
| Dubois and François . . . . . | 47·24 | 4·96 | 4·49 |
| Dunn . . . . . | 41·33 | 5·40 | 4·06 |
| Schram . . . . . | 45·27 | 5·71 | 4·92 |
| $2\frac{1}{2}$ atmospheres. | | | |
| Dubois and François . . . . . | 47·44 | 3·50 | 3·19 |
| Dunn . . . . . | 49·80 | 4·25 | 3·50 |
| Schram . . . . . | 40·16 | 4·14 | 3·58 |

The tool was changed twice in the Dunn drill, and only once in each of the two others: the Dunn drill bored the first 20 inches with a tool of $1\frac{3}{4}$ inch diameter, then about 10 inches with a $1\frac{9}{16}$ inch tool, and the remainder with a $1\frac{7}{16}$ inch tool; while each of the two other drills bored about half the length with a $1\frac{9}{16}$ inch tool, and the remainder with a $1\frac{7}{16}$ inch tool.

The power expended, as measured by the consumption of compressed air, was ascertained by charging the receivers of 2,440 cubic feet capacity with air at $3\frac{1}{2}$ atmospheres effective pressure, and noting the reduction of pressure that took place in boring a hole of $47\frac{1}{4}$ inches length and $1\frac{7}{16}$ inch final diameter; the same trials were repeated with $2\frac{1}{2}$ atmospheres initial pressure. The following were the results:

| Drill. | Effective Pressure in Receiver, in Atmospheres. | | | |
|---|---|---|---|---|
| | Initial. | Final. | Initial. | Final. |
| Dubois and François . . . . . | 3·50 | 3·05 | 2·50 | 2·05 |
| Dunn . . . . . | 3·50 | 3·01 | 2·50 | 2·06 |
| Schram . . . . . | 3·50 | 2·84 | 2·50 | 1·99 |

It must be observed that the Dunn drill, requiring two changes of tool and consequently a larger initial diameter of hole, pulverised 18 per cent. more rock in boring the above length than the Dubois and François drill, requiring only one change.

With regard to maintenance in working order, the Ferroux drill is considered preferable by M. Mativa in respect of its valve-gear and automatic feed, and the Dubois and François machine in respect of the rotation of the tool. Altogether, in respect of strength, simplicity, and durability, he places the Ferroux drill first; the Dunn and the Ingersoll next, with automatic feed; then the Schram and the Dubois and François, with hand feed. The Turrettini-Colladon drill, employed in the St. Gothard tunnel, he considers complicated, and consequently costly and troublesome in construction and maintenance. The Dubois and François, and the Ferroux machines, being fixed upon their stands or carriages by two points of attachment, one at each end, have a decided advantage in steadiness of working over those fixed at only one point, such as the Dunn, the Ingersoll, and the Schram, particularly for boring horizontal holes. A. B.

---

## *The Könyves-Tóth Hand Rock-Drill.* By E. Wawra.

(Mittheilungen über Gegenstände des Artillerie- und Genie-Wesens. Wien, 1878, p. 341.)

The arrangement consists of a guide tube bolted to a wood trestle in such a manner as to allow of its being clamped in any direction; a bar carrying the drill passes through and is guided by the tube; this bar is jumped up and down by hand, and by means of a spiral key-way and ratchet arrangement receives the proper amount of rotation at each stroke.

In practical work a considerable gain was found over the old method with jumper bar and hammer, provided the rock was not of an unusually hard character.

This drill was used with great success for removing rocks from the bed of the Danube in places where the blasting holes had to be drilled under water, and where the ordinary hand methods would hardly have been available.

W. P.

---

## *Employment of an Iron Caisson for Sinking under a Solid Shaft Head at Grosstadeln, near Leipzig.*

By C. W. Schulze.

(Jahrbuch für das Berg- und Hüttenwesen in Königreiche Sachsen, 1878, p. 35.)

The quicksands and other running measures, amounting to about 135 feet, and overlying a bed of brown coal in the neighbourhood of Leipzig, proving impracticable to deal with by ordinary systems

of piling, the above method was resorted to. The shaft having been sunk down to the level of the water, a depth of 17 feet, was lined throughout the upper 13 feet with close frame timbering, strengthened with corner and side pieces, and fastened together with flat bar iron. These frames were hung by similar bars to two oak bearing-frames, each 22 inches square. The shorter sides of these latter were dovetailed into the long lengths, which, projecting 14 feet at each end beyond the dimensions of the shaft, were bedded in cement. The size of the shaft inside the timbering was 14 feet 8 inches by 5 feet 10 inches. Below this solid shaft-head two sets of piles were driven behind the frames, the lower set penetrating through a fine gravelly sand immediately overlying the top quicksand. A few inches above the sand was placed a temporary platform, used while the caisson was being erected.

The caisson was made slightly larger than the dimensions of the shaft (the piling being purposely set back so as to enable its being fitted under the solid timbering) in order to allow of its being subsequently lined with timbering. It was formed of wrought-iron plates, flanged and bolted on the inside, the longer sides being strengthened by upright and cross pieces of wood. Round the upper edge a set-off was made, which formed a seating for the lowest frame required for the following down of the piling; and this ledge was strengthened by short diagonal stays from the wall. Four projecting arms had openings, through which passed strong iron guides of T rail section, firmly secured to the solid timbering above, and serving to insure the vertical sinking of the apparatus, any tendency to deviation being regulated by means of powerful screws fixed between the solid timbering and frame on the caisson; these screws were, if necessary, also used for forcing down the apparatus. The accidental sinking of the caisson could be guarded against by placing wedges in the guides. At the bottom of the caisson the walls were bolted to a shoe point of cast iron recessed so as to leave a flush joint; the cutting edge of this point formed an angle of 30° towards the inside of the caisson, and in the diagonal direction wrought-iron plates were bolted on. In the length of the caisson these plates were bent over so as to form a small horizontal ledge for holding down a platform by means of short props; horizontal plates, with small flanges for bolting on, connected the diagonal plates with the walls. The weight of the caisson was about 6 tons. Two small wrought-iron cylinders, with small openings for the passage of water in the upper parts, were provided, to be used as advance sumps, and were placed 11 inches apart. Before sinking, one of these cylinders was advanced to a depth of 3 feet 3 inches, precautions being taken to prevent flow of sand by protecting the outside with a casing of gravel, and similarly gravel was put inside for a height of 7 inches; but, in the event of much disturbance and tendency of the sand to run, a wooden cover was put over the gravel inside the cylinder and again gravel poured in. The second cylinder was afterwards sunk to a depth of 11 inches, and the caisson

5½ inches. The temporary platform was then replaced by a working one, and the latter weighted down from timbering. The platform consisted of a row of closely-fitted planks laid parallel to the shorter sides of the shaft (excepting the sections occupied by the cylinders, which had pieces suitably arranged). The ends of these planks and the joints of the pieces in the sump sections were overlapped by short planks; the platform had a margin of 8 inches between it and the shoe, and the cap pieces one of 2½ inches, the latter space being packed with leather and covered with gravel, unless, when passing through stiffer layers of clay, it was necessary to force stones from under the shoe by means of bars. The caisson was gradually sunk by means of screws, or its own weight, to a depth of 16½ inches below the platform, during which process the top planks were from time to time set back, being alternately strutted down from the ledge, and again isolated and kept down from the upper timbering. The caisson having reached the required depth, the planks of the platform were lifted one by one, and the ground cleared out, if practicable in two removals of 5½ inches, but occasionally only an inch or two could be removed at a time. The planks were replaced as soon as the underlying section of ground had been removed and strutted down. After the whole area had been cleared out to a depth of 11 inches, the platform was again isolated and the caisson sunk a farther depth of 11 inches. The operation was then repeated, the advance sumps or cylinders being in the meantime alternately worked past each other, one of them always being 11 inches in advance of the shoe.

When the sand started to run, on the removal of any of the planks, a coating of gravel was at once thrown in and the plank replaced, it being further necessary at times to put gravel over the plank joints. In like manner, the disturbance and tendency to run caused by the advancing cylinders was dealt with by throwing in quantities of gravel outside and inside, and clay was occasionally used round the gravel. In either case it was advisable to wait some time until the movement of the sand had subsided. When the gravel was removed from the inside cylinder the standard filter of 7 inches was left under the wooden cover while the second cylinder was being sunk. On one occasion, during the clearing of the ground in a layer of clay, several planks were removed at one time, and, working too near the point of the shoe, the sand broke away suddenly, and filled the shaft to a height of 13 feet in five minutes.

As the caisson was sunk the piling was carried on above. The piles were 6 feet long, 12 inches broad, and 1¾ inch thick, the driving end being chamfered off on the inside, and sometimes shod for driving through clay and gravel; the tops were protected with iron bands. The divergent line of piles was maintained by means of wedges placed between them and the frames, the last wedge being driven out on putting in the following set of piles. Behind the frame, on the caisson, was inserted a packing of heather

and gravel. At intervals of 9¾ to 13 feet the frame timbering was put in and hung in continuation of the solid shaft head, the space between it and the piling being well packed with gravel.

The feeder of water was about 40 cubic feet per minute, but at times suddenly augmented to three times as much. This might principally result from the sudden relief of water spaces; but the repeated throwing in of gravel, checking the flow, caused extra pressure behind walls and timbering, so that in sinking or driving the cylinders the water would come out in increased volume; to mitigate this evil the timbering was pierced, and, after the pressure was relieved, the holes plugged.

The pumping power consisted of two lifting sets of 13 inches diameter, and an auxiliary shaft with two sets of 11 inches diameter was put down to a depth of 54 feet, to ease the top water. The sinking of this pit presented no great difficulty, as it was kept free of water. The bucket and clack pieces were hinged, to admit of more ready access, and the windbore was provided with a leather casing, which could be raised or lowered to regulate the height of pumping. This was necessary in the event of sand rising in the sump, or threatening to flow towards the cylinder. The driving power was a 45-HP. portable engine, supplemented by another of 25 HP., for supplying steam; but the latter was arranged so as to admit of being coupled with the larger one; the auxiliary pumps were worked by a 16-HP. engine.

From December 26, 1874, to October 30, 1875, a depth of 44½ feet was sunk below water-level; at that depth firmer ground was encountered, and the farther sinking effected by piling, special care, however, being required. On the 2nd of August, 1876, the coal was struck at a depth of 137 feet; and on the 2nd of September the whole section of shaft was in the seam. The work would have been completed earlier had there not been a liberation of sulphuretted hydrogen gas, which seriously affected the workmen's eyes.

The cost of the caisson was £225: no working costs are given; but the labour required per shift of twelve hours consisted of:—one overman; six men for working the apparatus, attending to filters, &c.; two men attending to the cylinders and pump work; one engine man, who also looked after petty smith work; one waiter on; two winders; one runner; two carpenters. Another man was required during the liberation of gas to attend to the ventilator.

The caisson served throughout its length instead of timbering; but, as mentioned, it was made large enough to be lined with framing should it show signs of failing: the taking out of the caisson would necessarily have been a most dangerous operation.

This method of sinking is considered by the Author as more trustworthy and effective than that of forcing down walled cylinders.

A. S.

---

## *Increased Rarefaction by Combination of Centrifugal Ventilators.*

By J. HENIN.

(Revue universelle des Mines, vol. iii., 1878, p. 754.)

At Boubier colliery a Guibal fan of 25 feet diameter having become insufficient for the ventilation of No. 1 pit, owing to the extension of the workings, an additional centrifugal ventilator, on Lambert's plan, was erected close to it; and arrangements were made for working the two either separately or together, according to the requirements of the ventilation, and so as to obtain in the latter case a degree of rarefaction equal to the sum of the rarefactions produced by each separately. For this purpose the main air-drift from the upcast shaft is taken direct to the Lambert ventilator; near the commencement of the drift a branch is led off to the intake of the Guibal fan, and the discharge from this fan is delivered into a second branch, which re-enters the main drift a little before the intake of the Lambert ventilator is reached. Between these two branches are fixed in the main drift two doors, the closing of which shuts off the direct communication from the upcast shaft to the Lambert ventilator, so that the latter then draws from the Guibal fan. At seventy to seventy-four revolutions per minute, either ventilator working alone produces a rarefaction of about $2\frac{3}{8}$ inches column of water; when the two work in combination, the ultimate rarefaction in the upcast shaft is just double, amounting to about $4\frac{3}{4}$ inches.

A. B.

---

## *Materials for the Study of the Bessemer Process.*[1]

By E. CHERNOFF.

(Transactions of the Imperial Russian Technical Society, St. Petersburg, 1876–1877.)

In an exhaustive and elaborately illustrated essay on the Bessemer process as followed at the Abouchoff works, in Russia, and basing his opinion on numerous experiments with various kinds of pig-iron, English, Swedish, Oural, and Finnish, the Author comes to the following conclusions:

1. In order to obtain Bessemer steel of high quality, it is not indispensable to use any special kind of pig, it is only necessary that there should not be more than 0·1 per cent. of sulphur, phosphorus, copper, and other deleterious substances in the aggregate, and that the quantity of any one of them should not exceed 0·05 per cent.

2. The useful constituents of cast-iron, such as silicon and man-

[1] A translation of this memoir, *in extenso*, has appeared in the 'Metallurgical Review' (New York), 1878, pp. 457 *et seq.*

ganese, should together constitute about 1·5 per cent., and in order that the iron should be very fluid, it ought to be rich in carbon.

3. Poorness in silicon produces violent agitation; it is desirable in such cases to have the capacity of the converter at least twelve times that of the charge.

4. The capacity of the air-pumps should be such, as to enable about 1,600 cubic feet of air to be blown in per minute to the ton of pig.

5. The diameter of the blast orifices should not be less than 0·55 inch, and their collective area should be about 3·1 square inches to the ton of pig.

The adherence of very hot steel to the moulds, especially to the bottoms, may in a great measure be avoided by constantly moving the ladle, so as to prevent the stream of metal falling always on one place. After the cast is completed the ingot is covered with a cast-iron plate, with the view of hastening the cooling of the surface and preventing the formation and escape of gases. Without this precaution the ingot will not only turn out very porous, but the steel in cooling will spew over the edges of the mould. The surface of the steel after it has been poured into the moulds, exhibits in cooling a peculiar play, and the appearances presented indicate the temperature at which it has been worked, and to some extent its composition.

When the Bessemer process was first introduced into the Abouchoff works great trouble was experienced with the plugs or stoppers of the ladles, in consequence of their fire-clay coatings falling off, and thus exposing the iron rods to the full heat of the molten steel. Mr. Chernoff introduced annular fire-clay bricks, made with spigot and socket ends; these were threaded on to the stopper and set in fire-clay. The external diameter of the rings is $3\frac{1}{2}$ inches; the internal $2\frac{1}{4}$ inches; while the diameter of the stopper-bar is $1\frac{3}{8}$ inch. This method of protection has succeeded completely.

W. A.

---

## *Researches on the German Bessemer Process.*

By Dr. F. C. G. Mueller.

(Zeitschrift des Vereines Deutscher Ingenieure, vol. xxii., p. 386.)

The oldest Bessemer process is the one still maintained by all English works using the cupola furnace. This the Author calls the English process. The so-called "cold charge" is employed. At the commencement the temperature is only a little above the melting point of pig iron; the combustion of the carbon is consequently, during the first four minutes and at times for fifteen minutes, equal to zero. The silicon, however, is reduced from the first very rapidly, and the temperature is raised till the carbon burns, which takes place at about 1,400° C. If at the beginning the silicon does not exceed two per cent. it almost disappears at

about the middle of the process. The Author's Paper contains a number of percentage analyses of the German Bessemer process as carried out at Osnabrück, at the Hösch, the Dortmund Union, and the Bochum steel works. The leading feature of the process, viz., the second heating period at the end, is shown in the diagrams. In order to determine what influence the temperature has at the beginning of the process, it is necessary to know how the bodies composing the charge act as heating materials. In the converter 1 per cent. of silicon raises the temperature about 300° C. The carbon has no heating but a cooling effect, and is simply reduced to oxide. The absolute maximum temperature of this combustion is, however, 1,500° C., so that below this the carbon heats; above 1,500° C. it cools. When the difference does not exceed 100° C. 1 per cent. of carbon can only produce a change of temperature of 10° C. In addition to these calorific laws, the fact that the chemical affinity of the carbon for oxygen is equal to zero below a certain temperature, but increases rapidly above it, is of the greatest importance to the progress of combustion. The English cold charge shows that the fusing point of carbon is much higher than that of cast iron, whilst the silicon fuses at the melting point of pig iron, and raises the temperature of the charge till the carbon is consumed. In the German works the fusing point of the carbon is reached in the cupola; hence the rule that the sodium line must appear directly the blast is applied. The carbon and silicon are then consumed together and combine with the oxygen of the blast; as the affinity of the carbon, however, increases rapidly, it takes up a larger quantity, and in about five minutes the combustion of the silicon is completely suppressed. A strong and steady flame issues from the mouth of the converter with great noise. This the Author calls the period of eruption. The temperature is higher than the melting point of wrought iron, and, if this be taken at 1,600° C., the temperature at which the carbon is consumed, or the beginning of the German process, may be put at 1,400° C. When iron of the same composition flows at a temperature of 1,200° C. into the converter, instead of at 1,400°, the English process is developed. The Author gives data to show that the German process is a very difficult and expensive one, but that its introduction has been due to purely natural conditions. All the steel works in Germany first adopted the English method, but have after hard struggles been compelled to carry on their present system. English and Swedish Bessemer iron contains much less phosphorus than the German. With 0·4 per cent. of carbon, 0·1 per cent. of phosphorus gives a cold-short iron, whereas with 0·1 per cent. of carbon and 0·2 per cent. of phosphorus this is not the case, but such phosphorus-steel is as soft as wrought iron. The assertions made now and then that phosphorus has a hardening effect are erroneous. On the other hand, silicon gives hardness although in a much less degree than carbon. This hardness from silicon goes well with phosphorus, whilst that produced from carbon does not. By the English and Swedish processes the silicon is entirely eliminated, and only by

the German method is it possible to make Bessemer-steel rails from German pig iron. To carry out this method the charge must contain at least 1·4 per cent. of silicon and a little more than this quantity of manganese. It was doubtless by accident that the Bochum charge contained only 1·49 per cent. of silicon, as it is customary in Germany to employ a dark grey silicious iron, Nos. I., II., III., which contains about 1·9 per cent. of silicon from the cupola. More than 1·4 per cent. of silicon and of manganese does not of course materially alter the process. The curves are unchanged, but lie more above the abscissæ axis, and more silicon and manganese remain in the steel; the quantity that remains is not influenced by the carbon. A larger quantity of the latter increases the time occupied by the process, but on account of the high curve of the carbon an increase in quantity of 1 per cent. would not diminish the silicon remaining at the close of the eruption period by 0·1 per cent. It is clear that, with less than 1·4 per cent. of silicon, its combustion in the third period would hardly have commenced, and would be absent altogether with pig iron containing only 0·8 per cent. of silicon; with 1,400° C. initial temperature this quantity brings the charge to the eruption period, and can therefore develop a heat equal to the melting point of steel. The Author gives figures showing the quality of two samples taken from Bessemer-steel rails made at the Osnabrück works:

| | I. | II. |
|---|---|---|
| Absolute strength . . . . . | 70·7 | 62·0 |
| Contraction at the point of rupture | 43·6 per cent. | 38·5 per cent. |
| Longitudinal extension . . . | 24·0 „ | 19·0 „ |
| C | 0·144 „ | { 0·106 „<br>0·104 „ |
| Si | 0·435 „ | { 0·425 „<br>0·420 „ |
| Mn | 0·828 „ | 0·592 „ |

Such tenacity with so great an absolute strength is shown by no other metal but German Bessemer steel. There is no doubt that several causes have operated to develop the present metallurgical process, but it is beyond dispute that the phosphorus difficulty was the principal one. The Author draws attention to the excellent quality of the silicon steel containing phosphorus which is produced by most of the German steel works, and gives the following analysis, taken from Kerpeley's "Ungarns Eisensteine und Eisenhüttenerzeugnisse," of some Bessemer steel made at the Maximilian Smelting Works in Bavaria, as a standard of German production:

C = 0·10 – 0·15
Si = 0·4 – 0·7 – 1·18
Mn = 0·4 – 0·7
P = 0·1 – 0·15

The rest of the Paper is devoted to more minute details of the process and the analytical methods employed by the Author.

J. J. W.

## *Experiment on the Performance of Coke Furnaces under various Conditions of Draught, made by a Commission appointed by the Verein von Gas und Wasserfachmännern Deutschlands.*

(Journal für Gasbeleuchtung und Wasserversorgung, vol. xxi., pp. 355 and 386.)

The apparatus, furnace, &c., are described in detail, with drawings of the furnace, and the method of taking the observations is also fully explained.

The data given by the experiments are as follows: (1) Mean draught; (2) duration of experiment; (3) weight of fuel used; (4) weight of residue; (5) chemical composition of heating gas; (6) temperature in the gas passage.

(3) minus (4) gives the carbon used, and 1 cubic mètre of $CO_2$ and 1 cubic mètre of CO each contain equal weights of carbon (at 0° C. and 760 millimètres barometic pressure 0·5363 kilogramme). (5) gives the volume of $CO_2$ and CO contained in 1 cubic mètre of the heated gas, and consequently the weight of carbon in the same, which, by division in the total weight of carbon used, gives the volume of heated gas produced.

The following experiments (Table 1) were made with coke from

TABLE 1.

| Number of Experiment. | Pressure of Draught in Millimètres. | Kilogrammes in Twenty-four Hours of— | | | Percentage Composition of Heated Gas. | | | Quantity of Gas produced at 0°Cent. and 760 Millimètres Bar. | Temperature (Centigrade). | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Coke used. | Residue. | Carbon consumed. | $CO_2$. | CO. | $CO_2$ + CO. | | A. | B. | C. |
| I. | +0·74 | 785 | 111 | 674 | 2·0 | 28·3 | 30·3 | 4,110 | 500 | 500 | 725<br>750 |
| II. | +0·45 | 800 | 113 | 687 | 1·5 | 29·2 | 30·7 | 4,189 | 500<br>400 | 550<br>550<br>575 | 750<br>750<br>800 |
| III. | −0·60 | 1,200 | 151 | 1,049 | 1·8 | 28·6 | 30·4 | 6,396 | .. | .. | .. |
| IV. | −1·64 | 1,330 | 167 | 1,163 | 2·5 | 27·3 | 29·8 | 7,091 | 550 | .. | 800 |
| V. | −2·8 | 1,650 | 188 | 1,462 | 3·0 | 26·9 | 29·9 | 9,137 | 588*<br>700<br>700<br>750 | 714*<br>800<br>800<br>850 | ..<br>..<br>..<br>.. |
| VI. | −3·7 | 1,800 | 226 | 1,574 | 3·3 | 26·9 | 30·2 | 9,837 | 1,130 | .. | .. |
| VII. | −4·1 | 1,980 | 268 | 1,712 | 3·5 | 26·2 | 29·7 | 10,700 | 714* | .. | 748* |
| VIII. | −6·7 | 2,530 | 329 | 2,201 | 5·6 | 22·9 | 28·5 | 14,386 | 850<br>850<br>900<br>800<br>830 | ..<br>..<br>..<br>..<br>.. | ..<br>..<br>..<br>..<br>.. |
| IX. | −14·0 | 3,226 | 409 | 2,817 | 7·0 | 23·3 | 30·3 | 17,335 | 832* | .. | .. |

Saarbrück coal, supplied gratis by gas companies. The temperatures were measured by Siemens' water and electrical pyrometers; the observations were taken in this and all particulars in question as often as practicable, and the mean taken for the experiment. In experiments I. to IV., with low draught, the generator was moderately hot; in V. to VII. the generator was heated throughout; in IX., almost to white heat; and the temperature of the gas varied with that of the generator. The experiments lasted on an average about twelve hours each.

The temperatures marked (*) were measured with the electrical pyrometer, and at positions (A) centre of length of gas channel, (B) where channel joins furnace, (C) at the top of the furnace. The fire-brick lining of the furnace was not much injured at the low-pressure draughts, but sustained considerable damage when the air pressure was high, due to chemical action of the melted slag. Experiment VIII. was made with water put before the air ingress, which prevented the excoriation of the fire-brick, but at the same time reduced the temperature, as will be observed; 0·11 kilogramme of water was used per kilogramme of coke.

Another series of experiments was then made with coke obtained from Bohemian lignite. A great difference was now found in the formation of the slag as compared with the first series of experiments. The hearth-stone was not eaten away, but the slag solidified into a hard refractory mass at the draught-hole, which was removed with great difficulty. A sloping hearth-stone was accordingly tried so that the slag might flow away more readily; but still, with this alteration the generator could not be maintained in good working order, and at the close of these experiments it was found that the section of the generator had decreased from 1 mètre square to 0·36 by 0·6 square mètre owing to incrustation of slag. The next experiment was made to try the effect of the Saar coke in removing this crust, which it did in a short time. From observation during these last experiments a mixture of nine parts of lignite and one part of Saar coke was tried, which produced neither incrustation on the fire-stone nor chemical destruction thereof. Thus a judicious mixture of coke is most advantageous to the durability of the generator. Experiments were lastly made as to employing a grate and supplying steam with the draught. The water-tanks placed below the grate, when heated by radiation alone, did not give forth sufficient steam, and so they were subsequently kept at boiling point. The results surpassed all expectation. The slag formed as a friable mass, which was easily removed; at first the ashes were raked between the bars every two or three hours, but this was soon found superfluous, and the generator was left to itself, except for supply of material, for twelve or eighteen hours, and then the top of the generator was removed and all ash cleared out, which occupied only ten to fifteen minutes. The grate itself was completely preserved, being soon protected by a layer of non-conducting ash. This latter proved to be the best form of generator

for use with Bohemian lignite coke, as the loss of heat by radiation and conduction was greatly reduced, and less manual labour was required.

The actual results of experiments are given below in Table 2:

TABLE 2.

| Number of Experiment. | Pressure of Draught in Millimètres. | Kilogrammes in Twenty-four Hours of— | | | Percentage Composition of Heated Gas. | | | Quantity of Gas produced at 0°Cent. and 760 Millimètres Bar. | Temperature (Centigrade). | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Coke used. | Residue. | Carbon consumed. | $CO_2$. | CO. | $CO_2$ + CO. | | A. | B. |
| | | | | | | | | | ° | ° |
| I. | + 0·86 | 904 | 163 | 741 | 1·4 | 29·4 | 30·8 | 4,486 | 430<br>480 | 600<br>625 |
| II. | − 4·46 | 1,770 | 280 | 1,490 | 3·6 | 23·2 | 26·8 | 10,365 | .. | .. |
| III. | − 5·24 | 2,714 | 271 | 2,443 | 6·3 | 21·1 | 27·4 | 21,590 | 800 | 975<br>950 |
| IV. | − 0·55 | 1,462 | 362 | 1,100 | 1·8 | 28·2 | 30·0 | 6,837 | 750 | .. |
| V. | −11·8 | 3,707 | 487 | 3,220 | 12·5 | .. | .. | .. | 850 | .. |
| VI. | − 5·96 | 1,690 | 312 | 1,378 | 7·2 | 20·3 | 27·5 | 9,210 | 770 | .. |
| VII. | − 7·4 | 1,815 | 400 | 1,415 | 8·3 | 16·7 | 25·0 | 10,554 | .. | .. |
| VIII. | − 5·2 | 1,516 | 391 | 1,125 | 7·4 | 20·7 | 28·1 | 7,465 | 850 | 950 |
| IX. | − 4·6 | 1,338 | 351 | 987 | 3·6 | 25·0 | 28·6 | 6,435 | .. | .. |
| X. | − 8·2 | 1,920 | 384 | 1,536 | 5·6 | 23·4 | 29·0 | 9,876 | .. | .. |
| XI. | − 2·1 | 1,400 | 353 | 1,047 | 2·3 | 24·4 | 26·7 | 7,322 | .. | 950 |
| XII. | − 7·2 | 2,107 | 421 | 1,686 | 5·2 | 23·6 | 28·8 | 10,916 | 880 | .. |
| XIII. | − 3·1 | 1,610 | 274 | 1,336 | .. | .. | .. | .. | 730 | .. |
| XIV. | − 6·7 | 2,190 | 372 | 1,818 | .. | .. | .. | .. | .. | .. |
| XV. | − 6·2 | 2,160 | 367 | 1,793 | .. | .. | .. | .. | .. | .. |

Experiments I. and II. were made with the original form of generator and picked coke; III., IV., and V. with sloping hearthstone, picked coke and steam; VI., half-picked coke; VII., VIII., IX., and X., with unpicked coke; XI. and XII. with 9 parts Bohemian to 1 part Saar coke unpicked; XIII., XIV., and XV., with iron grate, introducing steam, and unpicked coke.

F. J.

---

## *Distillation of Petroleum Gas on the Scheuer System.*

(Il Politecnico, an. xvi. p. 622.)

The apparatus consists of a retort in the form of an inverted cone, placed in a closed furnace. The petroleum is introduced into this retort by an angular injector, which, by means of counterbalance weights, or of hydraulic power, is made slowly to revolve, so as to throw the oil over the interior of the heated surface of the

cone. The supply of petroleum is contained in a reservoir placed close by the chimney of the furnace, so as to be raised some degrees in temperature. The gas produced is made to pass first through a vessel of water, where it deposits the greater part of the tar which it contains. It then passes to a condenser, where the remainder of the tar is abstracted, then into a purifier, and thence through a meter, for distribution.

In the experimental proof made on the 3rd of September, 1878, to determine the economical value of the apparatus, the following results were obtained: 13·2 lbs. of wood, and 77 lbs. of coke were employed for heating the furnace, during 1 hour and 52 minutes. The temperature then obtained was 169° C., at which the distillation commenced.

The process of distillation lasted 2 hours and 13 minutes, employing 68·2 lbs. of coke; and the mean produce per hour was 437·226 cubic feet under a pressure of 3·15 inches. The production was regarded as below the full capacity of the apparatus; as the heat of the retort rose during the process from 169° C. to 220° C. After the close of the operation, 23·1 lbs. were removed from the furnace, and it was found that the distillation of 170·5 lbs. of petroleum had yielded 969·199 cubic feet of gas, being at the rate of 5·684 cubic feet of gas per lb. of petroleum.

On the examination of the retort, it was found that about half way up, exactly where the oil was thrown on the side of the retort by the injector, the meter was perfectly clean. Lower down there was a slight spongy incrustation, and on the upper part were found some small globules of graphite. It was concluded that the distillation could be carried on for 8 hours without stopping to clean out the retort, and that a daily production of gas, equal to the maintenance of 490 jets of the light of the standard Carcel burner, for 6 hours, might then be ensured.[1]

The total cost of the operation was 68·559 lire; and deducting 0·315 lira for the value of the residual products, the cost of 98·396 cubic mètres of gas amounts to 68·244 lire, being at the rate of 0·6036 lira per cubic mètre, or 0·0232 lira per burner. Translated into English equivalents, this gives a price of 18·8*d.* per 1,000 cubic feet, or 0·2227*d.* per Carcel burner per hour.

The comparison with gas is made by the exhibitors, the engineers Pietro Mantelli and Francesco Quadri, at the rate of a consumption of 120 litres per hour, and at the price of 0·35 lira per cubic mètre for coal gas. This is equivalent to a consumption of 4·29 cubic feet per hour, and to a price of 9·6*d.* per 1,000 cubic feet

[1] The French standard Carcel burner, which consumes 42 grammes of colza oil per hour, is taken by Mr. Kirkham (Min. Proc. Inst. C.E., vol. xxviii., plate 19) as equal to 9·6 English candles. A daily production of 3,497·811 cubic feet of gas, which is the equivalent of 98·976 cubic mètres, would thus be equal to the supply of 392 English Argand standard burners, of 12-candle power for 6 hours, the consumption being 1·49 cubic foot per burner per hour.

for the gas. The exhibitors deduce that the petroleum gas has $3\frac{1}{2}$ times the illuminating power of coal gas, at $44\frac{3}{4}$ per cent. lower price.[1] F. R. C.

---

## *The Mineral Production of Austria* [2] *in* 1877.

(Oest. Zeitschrift für Berg- und Hüttenwesen, xxvi., p. 377.)

I. PRODUCE of MINES.

| | Quantities. | Value. |
|---|---|---|
| | Tons. | £. |
| Gold ores | 105·2 | 1,278 |
| Silver ores | 9,561·5 | 310,725 |
| Mercury ore | 32,112·0 | 77,396 |
| Copper ore | 4,845·5 | 26,358 |
| Iron ore | 538,701·0 | 186,458 |
| Lead ore | 9,400·0 | 138,568 |
| Nickel and cobalt ores | 105·3 | 1,198 |
| Zinc ore | 24,002·0 | 34,245 |
| Tin ore | 786·0 | Not valued. |
| Bismuth ore | 0·12 | 46 |
| Antimony ore | 173·4 | 2,904 |
| Arsenic ore | 135·3 | 135 |
| Uranium ore | 7·0 | 4,989 |
| Wolfram ore | 39·5 | 335 |
| Chrome ore | 95·0 | 589 |
| Sulphur ore | 6,365·0 | 7,608 |
| Alum and vitriol schist | 147,661·0 | 9,195 |
| Manganese ore | 7,900·0 | 6,985 |
| Petroleum | 608·0 | 6,012 |
| Graphite | 11,858·0 | 53,338 |
| Asphalt | 79·0 | 95 |
| Lignite | 7,126,019·0 | 1,450,090 |
| Coal | 4,885,863·0 | 1,753,027 |

Total value of mining produce, £4,071,575, or 1·88 per cent. below that of the preceding year.

The average prices of lignite and coal were respectively 4·37 and 3·76 per cent. lower than in 1876.

---

[1] The comparison here to be made, for English use, should be at the lower price of 3*s.* 6*d.* or 4*s.* per 1,000 feet. It results that the Italian engineers allow 5·25 cubic feet of gas for the equivalent of an English Argand burner, instead of 5·00 feet, the parliamentary quantity. This quantity gives a light, they say, equal to that produced by 1·49 cubic foot of petroleum gas, which thus produces 3·3 times the illuminative power of coal gas. And as the price of petroleum gas, at 18·8*d* per 1,000 cubic feet, is less than half that of English gas at 42*d.* per 1,000 cubic feet, the proportionate cost, according to the figures given, will be about as 7 to 1; the petroleum gas being one-seventh of the cost of English coal gas for an equal illuminating power.

The average specific gravity of petroleum is given by M. Sainte Claire Deville as ·870. The heating power of 1 lb. is 20,240 British units of heat. It will be observed that the petroleum gas is above six times as heavy as ordinary coal gas. It contains 84·7 per cent. of carbon in 100 parts, against 66 per cent. in coal gas, so that its higher illuminative and lower evaporative power is intelligible from its composition. F. R. C.

[2] Exclusive of Hungary.

II. PRODUCE of METALLURGICAL WORKS.

| | Tons. | £. |
|---|---|---|
| Gold (280 oz.) | 0·0087 | 1,030 |
| Silver (873,493 oz.) | 27·169 | 242,093 |
| Mercury | 391·62 | 93,826 |
| Copper | 469·1 | 43,465 |
| Forge pig iron | 112,336·0 | 1,096,241 |
| Foundry pig iron | 34,365·0 | 277,459 |
| Lead | 5,314·0 | 131,328 |
| Litharge | 3,502·0 | 78,626 |
| Nickel | 14·0 | 1,974 |
| Zinc | 4,519·0 | 96,616 |
| Tin | 101·0 | 10,174 |
| Antimony | 42·1 | 1,472 |
| Arsenic | 24·0 | 607 |
| Uranium yellow | 4·5 | 9,600 |
| Sulphur and bisulphide of carbon | 305·0 | 3,524 |
| Copperas | 1,519·0 | 5,706 |
| Alum | 2,052·0 | 16,047 |
| Sulphuric acid | 9,739·0 | 129,481 |
| Vitriol stone | 5,895·0 | 14,712 |
| Mineral colours | 1,494·0 | 1,624 |

The total value of the metallurgical products was £2,255,603, or 5·89 per cent. less than that of 1876.

The production of salt was: 54,098 tons of rock salt, 149,111 tons of brine salt, 33,928 tons of bay salt, and 13,921 tons of manufacturing salt. The value upon the tons of the Government monopoly price was £2,232,381.

H. B.

---

## *Mineral Produce of Russia in* 1876.

(Oest. Zeitschrift für Berg- und Hüttenwesen, xxvi., p. 339.)

These returns, which are the latest published, do not refer to the civil year, but to the working year, which commences either on the 1st of May or 1st of September, and closes on the 30th of April, or 31st of August following :—

| | 1876. | Average of five years. 1871–75. |
|---|---|---|
| | Kilogrammes. | Kilogrammes. |
| Gold (1,081,752 oz.) | 33,647·0 | 35,310 |
| Platinum (50,670 oz.) | 1,576·0 | 1,741 |
| Silver (359,924 oz.) | 11,195·0 | 11,495 |
| | Tons. | Tons. |
| Lead | 1,168·0 | 1,236 |
| Copper | 3,873·0 | 3,712 |
| Zinc | 4,622·0 | 3,459 |
| Cast iron | 441,553·0 | 389,996 |
| Wrought iron | 292,699·0 | 275,128 |
| Steel | 17,916·0 | 9,039 |
| Castings | 48,917·0 | 42,000 |
| Coal of all kinds | 1,823,128·0 | 1,219,729 |
| Naphtha (petroleum) | 17,915·0 | 67,065 |
| Cobalt ores | 754·0 | .. |
| Graphite | 116·3 | .. |
| Nickel | 406·0 | .. |
| Chrome iron | 953·0 | 5,706 |
| Salt | 716,458·0 | 666,026 |

The total number of hands employed in gold washing, mining and smelting was, 285,788 in 1876, and 245,015 on the average of five preceding years. The above quantity of gold, when refined, gave 27,792 kilogrammes of fine gold. The amount of fine silver was 12,732 kilogrammes, the excess on the amount given above being due to the silver alloy separated from the gold in the parting process. H. B.

---

## *Receiving Instrument for Submarine Lines.*

(Annales Télégraphiques, 1878, p. 361.)

The currents employed on submarine lines being very weak, the electro-magnetic force of the receiving instrument is not sufficient to overcome the inertia of heavy moving parts in recording signals, and particularly the friction of the band of paper against the inker. Sir William Thomson has avoided the difficulty in his "Syphon-Recorder," and M. Ailhaud has designed an apparatus to fulfil the same end. Two horizontal horse-shoe electro-magnets are coupled to line and earth, and so arranged that their poles act upon two small magnets. These small magnets are connected by a rigid bar which is suspended by a fibre, and dips at its lower end into a mercury cup. This bar also carries a light aluminum arm, the bent end of which moves slightly above a chemically-prepared paper riband passing over a metallic roller. The roller and the mercury cup are connected to the two secondary poles of an induction-coil, so that a constant stream of sparks can be caused to pass between the end of the light arm and the prepared paper. The variations of magnetism in the electro-magnets caused by the signals are thus recorded by the movements of the magnets and arm upon the prepared paper. This instrument is worked on the Algiers-Marseilles cable with five battery elements, the paper being prepared with iodide of potassium solution and starch.

P. H.

---

## *Variations in the Strength of Electric Currents transmitted through imperfect conductors under Variation of Pressure exerted upon them.*

By COUNT DU MONCEL.

(Comptes rendus de l'Académie des Sciences, vol. lxxvii., p. 131.)

In this communication the Author recalls to the notice of the Academy the researches made by himself as far back as the year 1856 upon variations of electrical resistance under pressure, bearing as they do upon the more recent discoveries of Professor Hughes and Mr. Edison. These researches, and the accounts of them

published by the Author at the time, establish Count du Moncel's claim to the first discovery of the great principle upon which the microphone of Professor Hughes, and the micro-tasimeter of Mr. Edison depend for their action. In his experiments Count du Moncel made use of powdered carbon and a large number of other substances, and he found that variations of electrical resistance under variations of pressure were more marked in imperfect conductors than in bodies of smaller resistance, and that the resistance of metallic powders varied with their degree of aggregation. In his communication Count du Moncel calls attention to the fact that, in the year 1865, M. Clerac, an officer in the administration of French telegraphs, applied the same principle to the construction of cheap rheostats, which were long employed by the department for regulating the resistance of their lines. These instruments consisted simply of glass tubes filled with finely-divided carbon, upon which a piston or plunger was made to press by a screw at the end. To M. Clerac is therefore due the first practical application of the principle discovered by Count du Moncel, which has lately been independently applied by Professor Hughes and by Mr. Edison in the construction of their different instruments.

C. W. C.

---

## *On the Variation of Current under Modification of Pressure-Contact.* By M. Trève.

(Comptes rendus de l'Académie des Sciences, vol. lxxxvii., p. 405.)

If the circuit of a Faraday's or Ducretet's electro-magnet be closed between its two poles there is neither spark nor brush generally observed, but if the circuit be broken a detonation occurs nearly equal to that of a small pistol. The Author has shown that the same phenomenon is produced, but with less *éclat*, in the neighbourhood of a single pole of the electro-magnet, and at the present time calls attention to the fact that the former experiment admits of demonstrating to a very numerous auditory the influence of the pressure of contacts on the intensity of the current, since the loudness of the report may be considerably varied by greater or less pressure upon the wires before separation.

P. H.

---

## *A New Form of Tangent-Galvanometer for the Measurement of Powerful Currents.* By E. Obach.

(Repertorium für Experimental-Physik, vol. xiv., p. 507.)

In the ordinary form of tangent-galvanometer the exciting ring or coil is fixed in a vertical plane, and when employed for the measurement of powerful currents it is usual either to make the

ring of large dimensions, or to place the galvanometer in a derived circuit. Both these methods are open to objection, and the Author being desirous of measuring the strength of currents produced by dynamo-electric machines with nearer approach to accuracy than these methods afford, designed a galvanometer for the purpose. In principle this galvanometer is an ordinary tangent-galvanometer, with the addition that the ring can be inclined and clamped at any angle from the vertical to the horizontal, the axis of inclination being a horizontal line drawn through the point of suspension of the needle. In the vertical position of the ring, the setting of the galvanometer with relation to the magnetic meridian being as is usual, the current-effect upon the needle is at a maximum, but with the ring horizontal this effect is nil. The galvanometer, therefore, measures with proper inclination of the ring current-strengths between very wide limits; the readings taken with the needle at a given deflection, say 45°, will be proportional to the sines of the angles of inclination of the ring.

P. H.

---

## *Subdivided Electro-Magnet.* By P. GERMAIN.

(Annales Télégraphiques, May–June, 1878, p. 315.)

Considerable attention has been given to the reduction of the resistance in the coils of receiving instruments. In 1876 the Author introduced a Morse receiver, the coils of which offered only 3 ohms resistance with a line resistance of 500 ohms. These coils, by reason of the low resistance, admit of the suppression of lightning-arresters. In apparatus for rapid transmission there is still greater interest to reduce the resistance and increase the rapidity of magnetisation and demagnetisation of the soft iron, and with this in view the Author has designed a subdivided electro-magnet. Six small bobbins of soft iron, of total surface equal to that of an ordinary horse-shoe electro-magnet, are flat wound with a very thin plate of pure red copper. The spiral plates thus formed are insulated from each core by a vitrified dielectric, and laterally by an air-space. The six coils are coupled to form three electro-magnets, which are arranged upon the Hughes system.

P. H.

---

## *Experimental Researches on Magneto-Electric Machines.* By MM. MASCART and ANGOT.

(Journal de Physique, vol. vii., p. 79.)

*Reaction of the magnets and the electro-magnets.* The theoretical considerations indicated in a former article[1] give only a first

[1] *Vide* Minutes of Proceedings Inst. C.E., vol. i., p. 302.

approximation to the action of machines containing magnets or electro-magnets. It has been supposed that the magnetism of permanent magnets is invariable, and that that of electro-magnets depends only upon the intensity of the currents by which they are surrounded; but there exists between the magnets and the currents reactions that may greatly modify the results. Electro-dynamic machines which include neither magnet nor soft iron give rise to no new correction, the time necessary for the manifestation of the electro-dynamic forces being inappreciable. In magnetic machines of the second type, the effective magnetism of the permanent magnets is changed in a complex manner by the influence of the bobbins. If it be admitted that the variation of the magnetism of the magnets is proportional to the magnetic power of the bobbins, which is in direct ratio to the intensity of the current, it is to be seen that the magnetism of the magnets will be increased when they exercise an attraction between the two systems, and that it will be diminished in the case of repulsion. The diminution of repulsive force will be greater than the increase of attractive force, since the magnets may be supposed to be in a condition bordering upon saturation; there will result from this fact a slight diminution of work, and this may be represented by a term proportional to the square of the intensity of the current. The equations then become for the motor machine

$$K = N H = N I (A - B I)$$
$$E = N(A - B I = N\left(A - B\frac{E_0 - E}{R}\right).$$

Whence is deduced

$$E = N A \frac{I - \frac{E_0 B}{A R}}{I - N\frac{B}{R}},$$

instead of $E = N A$. The electro-motive force of induction, for a given velocity, is as much weaker as that of the battery is stronger. The machine left to itself has still a velocity, the limit of which is given by the condition $I = 0$, which is

$$N_0 = \frac{E_0}{A},$$

as if the reactions had not been taken into account.

The efficiency is diminished, because it has for expression

$$r = \frac{E}{E_0} = \frac{N A}{E_0} \frac{1 - \frac{E_0 B}{A R}}{1 - N\frac{B}{R}}.$$

To calculate the coefficients A and B the limit of velocity $N_0$ of the motor machine must be determined, whence is deduced

$$A = \frac{E_0}{N_0},$$

as measure for the efficiency for a given velocity; thus the equation

$$r = \frac{N}{N_0} \frac{1 - N_0 \frac{B}{R}}{1 - N \frac{B}{R}},$$

obtains, whence is deduced

$$B = R \frac{\frac{N}{N_0} - r}{N(1 - r)}.$$

The limit of velocity $N_0$ is easily obtained by experiment, since it is proportional to the electro-motive force of the battery employed, which may be chosen as weak as desired.

When the machine is employed as electro-motor the condition of production $\frac{K}{i} 2 > R$ is always realised for a very weak current, and equilibrium exists when

$$n\left(\frac{A}{i} - B\right) = R,$$

or

$$i = \frac{A}{\frac{R}{n} + B} = \frac{nA}{R + nB} = \frac{nA}{R} \frac{1}{1 + n\frac{B}{R}}.$$

The apparatus behaves as a battery, the electro-motive force of which is proportional to the velocity, with the conditions of adding to the actual resistance a fictitious resistance itself proportional to the velocity. The intensity will then have a limiting value given by the equation

$$i_\infty = \frac{A}{B}.$$

In magneto-electro machines, that is to say with fixed and moving electro-magnets, the influence of the wires of a system of bobbins on the opposed electro-magnets gives, as in the preceding, an increase of attractive forces and a greater diminution of repulsive forces, which again introduces into the work a negative variation proportional to the magnetism and to the intensity of

the current, that may be considered comprised in the term $C_1 M I^2$. On the other hand, the reciprocal influence of the electro-magnets gives also a diminution of work, which is sensibly proportional to the square of the magnetisation, and may be comprehended in the term $C_2 M^2 I^2$, so that there will be nothing to modify the theory. The reaction which was weak in the machines of the second type, plays on the contrary an important part in composite machines consisting of magnets and electro-magnets. If it be considered again that the magnetism of fixed magnets is modified by a quantity proportional to the magnetisation of the electro-magnets, there results a diminution of work proportional to the square of magnetisation, or to $M^2 I^2$.

The efficiency is

$$r = \frac{E}{E_0} = \frac{N(A + A_1 M)}{E_0} \frac{1 - \frac{E_0}{A + A_1 M} \frac{A_2 M^2}{R}}{1 N - \frac{A_2 M^2}{R}}.$$

If the current is sufficiently weak so that the coefficient M has the constant value $M_0$ it becomes

$$r = \frac{N}{N} \frac{1 - N_0 \frac{A_2 M_0^2}{R}}{1 - N \frac{A_2 M_0^2}{R}},$$

an expression of the same form as for machines of the second type.

*Magneto-electric Machines.*—The greater number of electric motors enter into this category because they are nearly always formed of two systems of electro-magnets—or, what is the same, of a system of fixed electro-magnets, and of movable pieces of soft iron. In these machines work has for expression

$$K = N H = N I^2 (C + C_1 M + C_2 M^2).$$

If the intensity is feeble the parenthesis may be represented by a constant A, and

$$K = N A I^2,$$

and the electro-motive force of induction is

$$E = N A I.$$

For the other part,

$$I R = E_0 - E = R I_0 - N A I,$$

whence is deduced

$$N A = R\left(\frac{I_0}{I} - 1\right).$$

The Gramme machine with electro-magnets enters into the same type in theory, but entirely differs from the preceding in con-

struction. This machine the Authors have studied as an electro-motor only. The resistance of the machine is not constant, because the commutator brush communicates successively with the different bobbins of the ring, but does not vary more than $\frac{1}{100}$th; the mean is 1·104 ohm. The authors have added successively exterior resistances to the amount of 200 ohms, and have varied the speed from a quarter of a revolution to nineteen revolutions per second. It should be remarked that this enormous speed can be obtained on very resistant circuits only, because the intensity increases so rapidly, that with a shorter circuit all the disposable power of the motor, which equalled 5 HP., could not be utilised. All the quantities are reduced into absolute units (webers), and the resistances expressed in ohms. The phenomena are regular when the resistance does not exceed 10 ohms, nor the speed of the machine ten revolutions per second. Thus, if the quantity is inferior to 0·08 weber, it is proportional to the speed, and in inverse ratio to the total resistance of the circuit. For larger quantities the constant has for expression $\frac{i\,R}{n}$, which depends only upon the intensity of the current. This result accords with theory. The electro-motive force is

$$n i\,(C + C_1\,M + C_2\,M^2),$$

which gives

$$i = n i\left(\frac{C + C_1\,M + C_2\,M_2}{R}\right), \text{ or } \frac{i\,R}{n} = i\,(C + C_1\,M + C^2\,M^2).$$

The values of $\frac{i\,R}{n}$ increasing nearly proportionally to the quantity, calculation can be effected by the following empirical formula

$$\frac{i\,R}{n} = 0{\cdot}286 + 0{\cdot}4\,i.$$

The Authors summarise the results of their experiments in a Table giving the quantity, resistance, and number of revolutions per second of $i$, R, and $n$, and of the calculated and observed values of $\frac{i\,R}{n}$.

P. H.

---

## *Motor for Electric Lamps.* By M. DE MERSANNE.

(Journal de l'Eclairage au Gaz, vol. xxvi., p. 263.)

In this system the carbon-holders or the carbons themselves are put in motion in one direction or another by a series of wheels, the last of which is fixed on the axis of a multiple armature having circular motion, commanded by two series of electro-magnets, the bobbins of which are traversed by derivations of the lighting current or by the lighting current itself. At the same time the

carbons receive a continuous motion regulated by the lighting current or its derivations, and causing in the arc neither enfeeblement nor interruption. The electro-magnets of each series are three in number, arranged to act upon ten armatures set upon the circumference of a wheel, and connected with a circuit-closing star-wheel as in electro-magnetic engines. By these two series of magnets, or two electro-magnetic engines, which are preferably worked by derivations from the main current, the carbons are moved apart or brought closer together as the resistance of the voltaic arc may regulate.

P. H.

---

*Baro-Electric Light Regulator.* By M. Bouteilloux.

(Journal de l'Eclairage au Gaz, vol. xxvi., p. 261.)

This apparatus consists essentially of two metallic tubes open at the two ends, and the lower ends of which are continued by tubes of insulating material. The diameter of these tubes is so chosen that carbon rods inserted in them may glide freely from one end to the other when the tubes are placed in a vertical or inclined position. The lower ends of the carbons rest on a support formed of magnesia or chalk, and the distance between them is regulated by a screw. As the carbons burn away they are brought into position on the support, relatively to each other, by their own weight.[1]

P. H.

---

*The Application of the Telephone to the Determination of the Magnetic Meridian.* By H. de Parville.

(Comptes rendus de l'Académie des Sciences, vol. lxxxvii., p. 405.)

When in the ordinary telephone the magnetised bar is replaced by a bar of soft iron of several mètres in length, the apparatus still transmits sounds, but with an intensity that varies according to the position of the bar with relation to the magnetic meridian. The maximum intensity of sound occurring at the receiver corresponds to the orientation of the transmitter. The sounds disappear when this telephone is placed in a plane perpendicular to the magnetic meridian. The Author considers that use could be made of this property in determining the compass-error at sea; and that by attaching to the receiver a self-recording apparatus such as is employed in Atlantic telegraph cables, the course of a vessel might be automatically and continuously recorded.

P. H.

---

[1] With the addition of magnesia or other refractory substance, this is the principle of Stait and Edwards' lamp (1863).—P. H.

## *A new Telephonic Transmitter.* By P. DUMONT.

(Comptes rendus de l'Académie des Sciences, vol. lxxxvii., p. 424.)

The Author obtains superior results by combining a string-telephone with an electric carbon-microphone. A parchment membrane 12 centimètres in diameter is stretched on a vertical frame. At the centre is fixed a string retained on one side by a knot, and carried on the other side to a small pulley, and supporting at its end a small brass cone suspended by a hook fixed at the centre of the base. This piece, comparatively rather heavy (20 grammes), plunges at the apex, to a depth of about a millimètre, into a metallic cup filled with powdered retort-carbon, and fixed on a horizontal plate, which, forming the base of the apparatus, supports the bar of the frame bearing the diaphragm. A battery of four Léclanché elements is included in the circuit, with an ordinary Bell telephone; and the variations of pressure of the cone upon the powdered carbon caused by movements of the diaphragm are transmitted to the receiver as electrical waves. P. H.

---

## *On some New Effects produced in the Telephone.* By COUNT DU MONCEL.

(Comptes rendus de l'Académie des Sciences, vol. lxxxvii., p. 390.)

The Author has put forward the opinion that in a telephone receiver the reproduction of speech could be attributed to molecular vibrations determined by the magnet and its armature (represented by the diaphragm) under the influence of successive magnetic increments and decrements resulting from the undulatory currents transmitted; but the use of the diaphragm especially was to reinforce the magnetic effects by its reaction on the bar, an increase that permitted the phonetic relations of articulate sounds to be perceived. This hypothesis was based on the facts, that electromagnetic bars emit sounds under the influence of frequently interrupted currents; that a Bell telephone without a diaphragm can reproduce speech; and that the low strength of the currents in a telephonic circuit renders the hypothesis of attractive action at a distance inadmissible. Mr. Hughes appears to have demonstrated by his microphone that if a magnetising coil, enveloping a bar of soft iron, is interposed in the circuit of a microphone, the ticking of a watch can be heard when the electromagnet is put close to the ear. By fixing the electromagnet on a plate of wood and adapting to this plate a second microphone, the sounds are amplified, and can be heard very distinctly in a telephone put in connection with the second microphone. The sounds can be still further amplified by applying one of the extremities of the electromagnet-core to one of the poles of a permanent magnet fixed on the plate. Then

articulate speech can be distinguished in the telephone in connection with the microphone mounted on the plate. If the electromagnet is placed between the two poles of a horse-shoe magnet the effects are still more marked. The two poles of a horse-shoe magnet being introduced together into the interior of the same coil give equally energetic effects, even though, by the fact of this arrangement, one of the poles may neutralise the effect of the other. But the most important effects have been obtained by placing a soft-iron armature across the poles of the magnet already introduced into the bobbin. In this case articulate sounds are very distinctly heard. If two vertical carbon microphones are fixed on the same horizontal plate, and one of these microphones is connected to a third serving as transmitter and the other to a telephone, and in each of the circuits a battery is introduced, words spoken before the transmitting microphone are heard in the telephone. The sounds are very feeble, but sufficient to show that in this manner a telephonic relay may be constructed without electromagnet or diaphragm. These experiments the Author considers to prove the theory he has advanced, which is farther confirmed in the receiving microphones. A simple piece of carbon is adapted to the centre of a disc of tin plate or copper, to which is applied, under pressure capable of regulation, another piece of carbon carried by an elastic and taut support. This apparatus can be employed either as transmitter or as receiver. When employed as transmitter, if the regulating screw be so released that the vibrations of the plate produce interruptions of the current through a small induction coil, and the induced current from this bobbin passed through a telephone in the circuit of which are interposed the two terminals of a small condenser of several plates, there will be repeated at this condenser airs sung before the transmitter, with such power that they can be heard throughout a room. They will be also reproduced in the telephone.

P. H.

---

## *The Physical Action of the Microphone.*

By COUNT DU MONCEL.

(Comptes rendus de l'Académie des Sciences, vol. lxxxvii., p. 7.)

The Author communicates an account of some experiments made with microphones of carbon and of other substances, such as has been suggested by Mr. Blyth of Edinburgh, confirming the truth of the discovery, that such instruments may serve not only as transmitters of feeble sounds but also as receivers. In the opinion of Count du Moncel, the investigation of the physical action of the microphone may lead to a correct explanation of the peculiar sounds which are sometimes heard in telegraphic receiving instruments, and he attributes their origin to the grating action of the conducting wires against their supports.

C. W. C.

---

## *The Sonorous Voltameter.* By T. A. EDISON, Ph.D.

(American Journal of Science and Arts, 1878, p. 379.)

The sonorous, or bubble voltameter, consists of an electrolytic cell with two electrodes, one in free contact with a standard decomposable solution, and the other completely insulated by vulcanized rubber, except two small apertures, one of which gives the solution free access to the insulated electrode, and the other allows the escape of bubbles of hydrogen as they are evolved by electrolysis. With a given current and a given resistance a bubble is obtained each second, which is seen at the moment of rising, and which at the same time gives a sound when it reaches the air. The resistance may be reduced so as to give one bubble in one, five, ten, or fifty seconds, or in as many hours. This instrument has been compared with the ordinary voltameter, and found to be much more accurate. By the use of a very small insulated electrode and but one aperture, through which both the gas and water current must pass, great increase of resistance takes place at the moment when the bubble is forming; and just before it rises a sounder-magnet included within the battery current opens, closing again when the bubble escapes; thus allowing, by means of a Morse register, the time of each bubble to be recorded automatically. This apparatus, when perfectly made, will be found very reliable and useful in some kinds of work, such as measuring the electro-motive force of batteries, &c. By shunting the voltameter, and using a recorder, it becomes a measure, not only of the current passing at the time, but also of that which has passed through a circuit from any source during a given interval.

*

---

## *Electrolysis of Cobalt.* By A. GAIFFE.

(Comptes rendus de l'Académie des Sciences, vol. lxxxvii., p. 100.)

In this Paper M. Gaiffe describes a method of depositing cobalt by electrolysis of the neutral double sulphate of cobalt and ammonia. Cobalt is less oxidizable than iron, and has the advantage of being more easily removed than nickel from the surface of other metals. Moreover, plates of commercial cobalt, cast without previous purification, will serve as anodes.

C. W. C.

---

## *Solar Radiation.* By A. CROVA.

(Comptes rendus de l'Académie des Sciences, vol. lxxxvii., p. 106.)

M. Crova has found that, while the intensity of solar radiation at the surface of the earth is affected by the amount of aqueous

vapour present in the atmosphere due to absorption during its transit, a large number of rays have already been absorbed before reaching the outermost limit of the earth's atmosphere. When the solar radiation is weakest, it is found that the telluric lines in the solar spectrum are most strongly defined. M. Crova obtained these results from a series of experiments, which measurements were made of the intensity of solar radiation at the surface of the earth, and after transmission through measured thicknesses of water and of aqueous vapour.

C. W. C.

---

## *Radiation of Heat.* By Signor VILLARI, of Bologna.

(Compte rendus de l'Académie des Sciences, vol. lxxxvii., p. 43.)

In this communication the Author records the results of a series of experiments conducted by himself on the radiating power possessed by bodies for different kinds of heat at a temperature of 100° C. There is, he finds, for every substance a certain thickness possessing maximum emissive power; for powdered rock-salt this thickness is 3·45 millimètres, and for Indian ink it is 0·03 millimètre. It varies with the purity of the substance employed, and may be measured directly by means of the spherimeter. To obtain the maximum effect with a blackened bulb thermoscope, the coating of lamp-black should be 0·2 millimètre thick. All bodies when heated to 100° do not emit heat rays of the same kind, but the differences between their thermic and their "thermo-chroic" radiative powers increase and decrease together. It is possible that existing data of the radiative power of bodies may require revising by the light of these discoveries.

C. W. C.

---

## *A New Explosive.* By P. HESS.

(Mittheilungen des Artillerie- und Genie-Wesens, p. 217.)

This article describes a new explosive discovered by Nobel, which, in the opinion of the Author, is very suitable for military purposes. It may be obtained by dissolving collodion cotton in nitro-glycerine. The result of the solution is a gelatinous or gummy substance, far more stable and powerful than Kieselguhr dynamite, and, unlike the latter, not affected by water. This new explosive, which is called "Blasting Gelatine," is in itself much less easily affected by blows than the ordinary Kieselguhr dynamite, but it may be rendered still more insensible to mechanical impulse by an admixture of a small portion of camphor; the addition of this latter substance does not affect the explosive powers of the compound. It is thus composed of 90 per cent. of nitro-glycerine and 10 per cent. of soluble

nitro-cellulose, the camphor subsequently added varying from 4 per cent. to 10 per cent. by weight, in quantity. With this composition, it is a gelatinous, elastic, transparent, pale-yellow substance, having a density of 1·6, and the consistence of a stiff jelly. The special advantages claimed for this new explosive are the following:—(1) that it possesses greater strength, weight for weight, than ordinary dynamite; (2) that it exhibits a high degree of insensibility to blows, friction, &c., although it may be relied upon to explode when the proper initial impulse is applied; (3) that it may be burned without danger, no explosion attending the combustion of large masses of it; (4) that it is very stable, and retains its explosive powers and other properties for long periods, and under all ordinary conditions of transport; and (5) that it is unaffected by water. This latter property admits of its being left for a long time in a moist atmosphere, or even under water, without deteriorating. Elaborate experiments have been carried out, the result of which is to prove that the new preparation is, weight for weight, 25 per cent. stronger than Kieselguhr dynamite. Their densities are 1·6 and 1·4 respectively, therefore as their relative strengths for equal weights are as 5 : 4, the same for equal volumes must be $5 \times 1{\cdot}6 : 4 \times 1{\cdot}4 = 10 : 7$; therefore the new explosive is, bulk for bulk, more than 40 per cent. stronger than Kieselguhr dynamite. It was also proved by experiment that the relative strength of gelatine and wet gun-cotton for equal volumes—presupposing that wet gun-cotton and ordinary dynamite have, weight for weight, the same strength—is as 174 : 100, or that gelatine is, by bulk 75 per cent., and by weight 25 per cent., stronger than gun-cotton. From these facts it is clearly possible to send into the field 25 per cent. more explosive power, with an equal weight of material, if gelatine be used in place of dynamite; and also that in a powder magazine of given capacity there can be stored up 40 per cent. more explosive power if dynamite be replaced by gelatine. This is an obvious advantage, inasmuch as the magazine may be made proportionately smaller, and, in consequence, more easily built. The addition of 4 per cent. of camphor increases the insensibility of the explosive to mechanical impulse almost as much as the addition of 15 to 25 per cent. of water to compressed gun-cotton; indeed, it has been shown experimentally that gelatine containing 1 per cent. of camphor exhibits almost enough insensibility for all practical purposes. With 4 per cent., its insensibility to blows—even to musket shots—is complete. In this respect it nearly equals gun-cotton, and far excels Kieselguhr dynamite. If large masses of compressed gun-cotton or dynamite be ignited, or if the gaseous products have not sufficient escape, or, again, if part of the unburnt mass becomes heated, there is danger of an explosion; in the case of gelatine, however, this contingency is to a great extent avoided by reason of the high temperature at which it explodes. This temperature, according to experiments made by the Author, is about 204° C. if the gelatine be heated gently; when heated quickly it explodes at 240° C. But on addition of 4 to 10 per cent.

of camphor, this point may be raised to 300° or 330° C. Blasting gelatine requires a specially strong primer, composed of cellulose-dynamite, in the proportions of 60 per cent. of nitro-glycerine, and 40 per cent. of nitro-cellulose. Owing to its insensibility to blows and high temperature, it cannot be exploded by the ordinary fulminate detonator. As regards the stability of the preparation, two points present themselves for consideration: the possible volatilisation of the camphor and the possible gradual decomposition of the nitro-glycerine, or of the gun-cotton, or of both compounds. It is shown by experiment that the camphor does volatilise, but that the process is too slow to affect the certainty of the preparation within reasonable limits of time, and also that gelatine is quite as durable as compressed gun-cotton, and much more so than Kieselguhr dynamite. The cost of production of the new explosive is half as much again as that of dynamite, and about the same as that of gun-cotton.

G. G. A.

---

## *On the Ventilation of the transport Steamship 'Annamite.'*

By L. E. Bertin.

(Bulletin de la Société d'Encouragement, 1878, pp. 442, 445.)

The 'Annamite' is employed in the service between Toulon and Saïgon, in Cochin-China, and there is accommodation on board for nearly six hundred persons, one hundred of whom, consisting of officers and others, are lodged in cabins In the central portion of the lower battery, there is room for four hundred and eighty ordinary passengers, who sleep in hammocks, each of which occupies a horizontal area of about 10 square feet, corresponding to a capacity of 70 cubic feet between decks. Aft, there is accommodation for thirty-eight persons, third-class passengers, and females; forward, there is sleeping room for one hundred and twenty seamen. It is assumed that the number will not exceed four hundred in the central portion, and thirty aft, except in very exceptional cases; making with the seamen, in all, five hundred and fifty persons. The quantity of fresh air required for this number of persons, allowing 1,060 cubic feet per hour per man, amounts to a total of $(1{,}060 \times 550) = 583{,}000$ cubic feet per hour. To provide a change of air at this rate, the whole of the air between decks must necessarily be renewed in $8\frac{1}{2}$ minutes. The supply of fresh air is brought by two currents, and is distributed by two conduits running fore and aft, between decks. Close to the upper deck, the spent air is withdrawn to the right and left through numerous openings at the sides, a little above the level of the deck, and is collected and transmitted in an enclosed passage at each side to two ventilating furnaces placed beside the steam-boilers. Thence, the air, heated, is discharged into a jacket surrounding the chimney, in which it rises, and from which it is

discharged at the level of the top of the chimney. The space enclosed by the jacket is divided into four vertical compartments, two of which are devoted to the ventilation of the lower battery, and the other two to that of the upper battery. The special ventilating furnaces are not required when the furnaces of the boiler are alight, as then the heat from the chimney is communicated to the ascending columns of air in the jacket. The upper battery contains accommodation for first-class and second-class passengers, for seamen, and for the hospital. The hospital is ventilated artificially. The other parts of the battery are sufficiently ventilated by the hatchways and the ports. To ventilate the hospital, the air-passages are placed transversely. The fresh air, brought down by two funnels, is delivered at the two extremities of the hospital, and the spent air is taken off at the centre, whence it proceeds direct to the chimney-jacket. The lobbies are separately ventilated. The ventilation of the hospital is proportioned for one hundred and twelve invalids, at the rate of 1,624 cubic feet of fresh air per man per hour, making, for all, about 182,000 cubic feet per hour. For an average number of eighty invalids, the Author estimates a supply of about 152,000 cubic feet of fresh air per hour, corresponding to a complete renewal in 7·1 minutes.

The passages from the lower battery have a total sectional area of 32 square feet, so as to exhaust, at a speed of about 5 feet per second, about 290,000 cubic feet of spent air per hour, which is not much less than the estimated amount already given, 303,600 cubic feet.[1] For the hospital, a total section of conduits of about 13 square feet is provided, so as to exhaust, at a speed of about 5 feet per second, 178,000 cubic feet per hour.[2]

In a Report by General Morin, the results of experiments on the ventilation are given, and are here briefly abstracted :—

| Fires alight. | Volume of Air per Hour. | |
|---|---|---|
| | Lower Battery. | Hospital. |
| | Cubic feet. | Cubic feet. |
| Two ventilating furnaces only . . . | 642,300 | 290,000 |
| Four boilers only, in eight . . . . | 708,930 | 315,690 |
| Means . . . . . | 675,600 | 302,800 |

These quantities are considerably in excess of the calculated quantities. The natural draft, aided only by the heat from the

[1] There appears to be a mistake in the original text. The quantity calculated from the given data above, is 576,000 cubic feet. The estimated amount was 583,000 cubic feet per hour.

[2] There is here, again, in the original, apparently a mis-reckoning. The quantity, calculated from the above data, is upwards of 230,000 cubic feet; the estimated maximum quantity was 182,000 cubic feet per hour.

kitchen, with a breeze in fine weather, at a temperature of 68° Fahr., yielded 208,600 cubic feet per hour for the hospital, and 543,000 cubic feet per hour for the lower battery.

D. K. C.

---

## *Note on the so-called Blue Process of Copying Tracings.*

By P. BARNES.

(Read before the American Institute of Mining Engineers, February 1878.)

This process, which is photographic—the tracing taking the place of the ordinary glass negative—can be employed with excellent results, and with an important saving of time and money, if only one or two copies are required of ordinarily complex drawings. The formula for the sensitizing solution is $1\frac{7}{8}$ oz. of citrate of iron and ammonia and 8 oz. of clean water, and $1\frac{1}{4}$ oz. of red prussiate of potash and 8 oz. of clean water. The chemicals should be dissolved separately and afterwards mixed, the solution being kept in a yellow glass bottle, or carefully protected from the light. This solution is applied to any good hard paper that will bear the necessary wetting. A sponge 4 inches in diameter with one flat side is a convenient means of coating the paper, which should be gone over once, the sponge being quite moist with the solution, and a second time squeezed dry. The sheet must then be laid in a dark place, and be shielded from the light until used. When dry the paper is of a full yellow or bronze colour, which deepens on exposure to the light. The manipulations required are of the simplest kind. Two or three thicknesses of common blanket or its equivalent are laid on the drawing board; on this yielding bed the sensitized paper is placed face uppermost, the tracing is then carefully smoothed over the prepared paper and covered with a plate of clear glass, which should be heavy enough to press the tracing close down on the paper. Ordinary plate glass of $\frac{3}{8}$ inch thickness suffices. The whole is next exposed to the sun for from six to ten minutes. If only a clear skylight is available the exposure must be continued for thirty or forty-five minutes, and under a cloudy sky sixty to ninety minutes may be required. The prepared paper is then removed, drenched freely for one or two minutes in clear water, and hung up by one corner to dry, when the characteristic blue tint will appear, with the lines of the tracing in vivid contrast. A solution of carbonate of soda or potash, used with a pen or brush, affords a ready means of adding to or correcting the blue copies.

F. G. D.

---

# INDEX

TO THE

# MINUTES OF PROCEEDINGS,

## 1878–79.—PART I.

ABERNETHY, J., remarks as to harbour and dock works, 49.—Ditto as to the early construction by the Bristol Port authorities of docks for ocean steamers, 49.—Ditto as to the great difficulties attendant upon the construction of works on such a site as that of the Avonmouth dock, 49.—Ditto as to the various projects for canalizing or dockizing the Avon, 49.—Ditto in deprecation of any attempt to diminish the tidal flow in navigable rivers, 50.—Ditto as to Belfast harbour, 50.—Ditto as to Whitehaven harbour, 50.—Ditto as to the tendency of solid groynes projected from sandy foreshores to advance the low-water line seaward, 50.—Ditto as to the doubtful success to be anticipated from the projected new harbour at Boulogne, 51.—Ditto as to the difficulty of constructing deep-water harbours on sandy coasts influenced by littoral currents, 68.—Ditto as to the North pier at Aberdeen, 68.—Ditto as to the entrance to the Amsterdam canal, 68.—Ditto as to his reasons for predicting the silting up of the proposed harbour at Boulogne, 69.—Elected vice-president, 174, 206.

Abstracts of papers in foreign transactions and periodicals, 336.—Ditto referred to in the annual report, 181.

Accounts, auditors of, appointed, 173.—Review of the financial position of the Institution in the annual report, with statement of the trust and other funds belonging to, or under the charge of, the corporation, 184.—Abstract of receipts and expenditure from the 1st of December, 1877, to the 30th of November, 1878, 188.

Agthe, A., on double-hook couplings for rolling stock, as replacing safety chains, 393.

Air, experiments on the flow of, through orifices in a thin plate, 379.

—— -compressors and rock-boring machines, 411.

—— -lock doors, securing, in sinking by compressed air, 354.

Airy, W., "On the Slopes of Cuttings," 241.

Aitken, R., remarks as to harbour and dock works, 83.—Ditto as to whether the projection of solid piers from sandy foreshores tended to advance the level of low water seaward, 84.—Ditto as to the effect of the abstraction of shingle on the South Eastern railway between Folkestone and Dover, 84.—Ditto as to whether engineers in designing works were bound to provide for more than a certain number of years, 85.—Ditto as to the best means for maintaining the stability of dock and other retaining walls, 85.

Amenduni, G., monograph on the torrents on the coast of the Ionian sea between Reggio and Assi, in the province of Calabria Ultra, 364.

Andros, A. C., remarks as to harbour and dock works, 89.—Ditto as to a dock at Workington with an unpuddled bottom, 90.
Angot, M. *Vide* Mascart.
"Annamite" s.s., ventilation of the, 441.
Annual general meeting, 173.—Annual report, 175.—Ditto read and ordered to be printed, 173.
Arches, determination of the thickness and form of the arches of stone bridges, 344.
Armstrong, J., admitted student, 124.
————, Sir W. G., elected vice-president, 174, 206.
Arnott, Dr., his system of ventilation referred to, 152.
Austria, mineral produce of, in 1877, 426.
Avonmouth dock, the, 3. *Vide* Dock.
Axle, self-lubricating hollow, for mining wagons, &c., 398.

Bache, A. *Vide* Marsaut.
Baker, W., elected member of council, 174, 206.—Memoir of, 315.
Baldry, J. D., appointed one of the scrutineers of the ballot for council, 173.—Vote of thanks to, 174.
Balzberg, C. von, on Piccard's apparatus for evaporating brine without fuel, 409.
Bancroft, H., transferred member, 124.
Barber, E. S., transferred member, 124.
Barlow, W. H., elected vice-president, 174, 206.
Barnes, P., note on the so-called blue process for copying tracings, 443.
Basire, M. de. *Vide* Béral.
Bateman, J. F., elected President, 174, 206.—Vote of thanks to, 173.
Bauerman, H., "On the Progress of Mining and Metallurgy in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874-78," 297.
Baxter, W., elected member, 124.
Bazalgette, Sir J. W., C.B., elected member of council, 174, 206.
Belfast harbour, 22. *Vide* also River Lagan.
Belfield, F. W., admitted student, 124.
Bell, H. P., transferred member, 124.
Bell and Miller, Messrs., their recommendations for the improvement of Belfast harbour, 27.
Béral, M., and de Basire, M., conditions for the establishment of secondary railways, 388.
Bérard coal-washing apparatus, description of the, 267.
Bergeron, C., remarks as to the proposed deep-water harbour at Boulogne, 74.—Ditto as to the report of Messrs. Stoecklin and Laroche, upon the improvement of that port, 75.
Berkley, G., elected member of council, 174, 206.
Bertin, L. E., on the ventilation of the transport steamship "Annamite," 441.
Bessemer process, materials for the study of the, 418.
———— ————, researches on the German, 419.
Bidder, G. P., past-president, notice of the death of, 177.
————, S. P., notice of the death of, 177.
Blast furnaces. *Vide* Mining metallurgy..
Blasting gelatine, 439.
Blomfield, V. J. S., admitted student, 124.

Boilers, steam, evaporative performance of, and corrosion, and incrustration of. *Vide* Machinery.
Bolckow, H. W. F., M.P., notice of the death of, 177.—Memoir of, 325.
Boring machinery. *Vide* Air compressors, also Mining and metallurgy.
Boston, U.S., water supply, the, 385.
Bourke, W. L., admitted student, 124.
Bouteilloux, M., baro-electric light regulator, 435.
Bowen, C., opinion of, as to the privileges of Associates of the Institution, 175.
Boyd, J., notice of the death of, 177.—Memoir of, 326.
Brady, J., transferred member, 124.
Brakes, continuous. *Vide* Public works, also Railway brakes.
Bramwell, F. J., elected member of council, 174, 206.
Bredt, R., on testing machines for iron and steel, 408.
Bremner, A., admitted student, 124.
Bretherton, N., admitted student, 124.
Bridge, Königswart. Iron bridge over the river Inn at Königswart, near Wasserberg, 347.
———, Magdeburg. Substitution of a single span for two openings of the Magdeburg railway bridge, 352.
———, Schandau. Queen Carola bridge over the Elbe, near Schandau, 350.
Bridges, draw-. On the strains produced in arched drawbridges by wind pressure, 345.
———, iron and steel. *Vide* Public works.
———, stone, determination of the thickness and form of the arches of, 344.
Brine, Piccard's apparatus for evaporating, without fuel, 409.
Bristol Port and Channel Dock Company, Avonmouth dock of the, 3. *Vide* Dock.
Browne, W. R., remarks as to the Avonmouth dock, 54.—Ditto as to the slip in the dock wall, 55.—Ditto as to the lock gates, 56.—Ditto as to the foundations 57.—Ditto as to his opinion that the tidal flow up and down a river was an absolute and unmitigated evil, 58.
Bruce, G. B., elected member of council, 174, 206.
———, W. D., his system of screw-pile jetties, constructed in the Hooghly at Calcutta, referred to, 106.
Brunel, I. K., his proposal of 1839 for the construction of docks in the Avon and a floating pier at Portishead, referred to, 4.
Brunlees, J., elected vice-president, 174, 206.
Buckham, T., notice of the death of, 177.
Bye-laws and regulations, special general meeting for the enactment of new, and the alteration and repeal of existing, November 5, 1878, 1.—Ditto December 2, 1878, 121.

Caisson, iron, employment of an, for sinking under a solid shaft head at Grosstadeln, near Leipzig, 414.
Canal. "The Eastern Canal of France; for establishing a line of water-communication from the Saône to the Meuse," 207.—Urgent reasons for the construction of the canal, consequent upon the loss of Alsace to France, 207.—Scheme as at present being carried out, 208.—The canal from the Moselle to the Saône, 209.—Marne-Rhine canal, 209.—Summit level, 211.—Locks, 212.—Amount of water required for the summit reach, and reservoir established to maintain the supply, 213.—Water required for the whole canal, 215.—St. Etienne mill-dam, 216.—Tunnels at Épinal, 216.—Bouzey reservoir, 217.—

Canalization of the Meuse, 219.—Present condition of the Meuse above and below Verdun, 219.—Canalization project authorised in 1861, 220.—Necessity for supplying the summit reach by pumping, and quantity of water required, 221.—Impounding reservoir across the valley of the Vraine, 225.—Course of the Eastern canal from Pagny to Verdun, 225.—Construction of the canal works at Verdun, 227.—Course of the canal from Verdun to Sedan, 228.—Needle dams in the canal, 229.—Modification of the needle dam by M. Chanoine for use in the Belgian Meuse, 230.—Necessity for enlarging tunnels on the Meuse below Charleville, 232.

———, Gand and Terneuzen, excavators and silt shoots employed on the, 379.

———, Ganges. On the construction of the Narora works, head of the Lower Ganges canal, 371.

———, Marne-Rhine. *Vide* Canal, the Eastern, of France.

———, Saint Louis, mouth of the Rhone, mode of constructing quay walls at, referred to, 105.

Cement, Portland, regulations for the uniform supply and testing of, 336.

" Chalk Water Supply of Yorkshire, the," 252. *Vide* Water supply.

Chambrelent, M., his report on the drainage of the " Landes " of Gascony, 234.

Chanoine, M., his modification of Poirée's needle dam, described, 230.

Chapman, W., his proposal (1821) for the improvement of Whitehaven harbour referred to, 36.

Chauntler, F., admitted student, 124.

Chernoff, E., materials for the study of the Bessemer process, 418.

Civil engineering in foreign countries, recent progress in. *Vide* Electrical science, Machinery; Mining and metallurgy; and Public works engineering.

Clark, D. K., "On the Progress of Machinery in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874-78," 286.

——-, Leslie, elected member, 124.

" Coal-Washing Apparatus at Bessèges, France," 259.—Principle upon which all coal-washing apparatus depends, 259.—Theoretical investigations of Herr Rittinger, 259.—Sorting by equivalence, 260.—Evrard's circular washer, 262.—Partial filtration washers, 262.—Ascending current washers, 262.—Preliminary sizing by riddling, 263.—Old piston jiggers at Bessèges, 265.—Bérard coal-washer, 267.—Modified Bérard coal-washer, 268.—Coal-washing apparatus at Molières, 269.—Marsaut coal-washer, 271.—Comparative results of the Marsaut and the modified Bérard washers, 274.

Cobalt, the electrolysis of, 438.

Coke furnace. *Vide* Furnaces.

Cofferdams, comparative advantage of different types, 7 *et seq.*

Coley, W. H. W., admitted student, 124.

Combustion, slow, under pressure, 399.

Compound engines. *Vide* Machinery.

Conservatoire des Arts et Métiers, at Paris, ventilation of the, referred to, 162.

Constantine, J., remarks as to the heating and ventilating of Glasgow University, 149.—Ditto as to the lesser cost which a system of natural instead of artificial ventilation would have entailed, 149.—Ditto as to the ventilation of the Free Trade Hall at Manchester, 149.—Ditto ditto Royal Exchange, Manchester, 151.

Coode, Sir J., his proposal of 1866 for the improvement of Whitehaven harbour referred to, 39.—Remarks as to harbour and dock works, 85.—Ditto as to the necessity now existing for making docks big enough to take steamers 500 feet

long, 86.—Ditto as to concrete-mixing machines, 86.—Ditto as to the asserted disadvantages of tidal flow in rivers, and as to the fallacy of supposing that a head of 35-feet of water would avail for effectual sluicing, 87.—Ditto as to Mr. Abernethy's condemnation of ports on sandy shores not always holding good, 88.—Ditto as to the alleged effect of the removal of Round Down cliff on the travel of the shingle east of Folkestone, 88.—Ditto as to his not meaning to say that a dock should be 600 feet wide for the whole of its length, 89.—Elected member of council, 174, 206.

Corthell, E. L., the South Pass jetties, Mississippi river, 367.

Council, ballot for, 173.—Annual report of, read and ordered to be printed, 173.—Vote of thanks to, 173.—List of council and officers for the session 1878-79, 174, 206.

Couplings, double-hook, for rolling stock, 393.

Couvreux, M., his excavators, silt shoots, and pile drawers, employed in canal and river works, described, 378.

Cowper, E. A., remarks as to the heating and ventilating of Glasgow University, 151.—Ditto as to the modern ideas of ventilation being not always practicable of fulfilment, 152.—Ditto as to the undesirability of putting crowded and empty class-rooms on the same footing in respect of the supply of warm air, 152.—Ditto as to the system of forced ventilation advocated by Dr. Arnott and Dr. Reid, 152.—Ditto as to the wooden pumps used by Mr. Oldham at the Bank of Ireland, and at the Bank of England, 153.—Ditto as to a temporary remedy for the inconvenience of cold air arising from contact with the windows, 153.—Ditto as to the warming and ventilation of Sir C. Fox's drawing office at Smethwick, 153.—Ditto as to the advantages of pressure in excluding draughts, 154.—Ditto as to centrifugal fans being better than screw ventilators, 154.—Ditto as to the best velocity for the delivery of the air, 155.—Ditto as to a fan for ventilating the Stamping Department of the Inland Revenue Office, 155.

Crova, A., solar radiation, 438.

Cunningham, G. C., elected member, 124.

Current, electric, on the variation of, under modification of pressure contact, 429.

Currents, electric, a new form of tangent-galvanometer for the measurement of powerful, 429.

———, variations in the strength of electric currents transmitted through imperfect conductors under variation of pressure exerted upon them, 428.

Currey, C., notice of the death of, 177.—Memoir of, 327.

Cuthell, A., notice of the death of, 177.

Cuttings. "On the Slopes of Cuttings," 241.—Forces tending to prevent the falling in of the sides of a cutting, 241.—Mathematical determination of the minimum curve of equilibrium of a slope in ground of uniform character, 242.—Experiments to ascertain the co-efficients of weight, cohesion, and friction, 245.—Irregular ground, 249.—Remarks on the maintenance of slopes, 249.

Daft, T. B., memoir of, 329.

Dam, Poirée's needle, on the Eastern Canal of France, described, 230.

——, Rappersweil, Zurich, 376.

Dams for impounding water. *Vide* Public works.

Daniel, C. E., remarks as to the cost of the Avonmouth dock works, 64.

Darrach, C. G., the flow of water in pipes under pressure, 381.

Dawson, W. B., "The Eastern Canal of France: for establishing a line of water-communication from the Saône to the Meuse," 207.

Denham, Capt., R.N., his report of 1836 on the improvement of Whitehaven harbour, referred to, 38.
Desert land. *Vide* Land.
Dock. "The Avonmouth Dock," 3.—Early history of the port of Bristol, 3.—Plans proposed by different engineers between 1828 and 1858 for providing more dock accommodation, 4.—Undertaking of "The Bristol Port and Channel Dock Company," 5.—General plan of the Avonmouth dock, 5.—Tides, 6.—Temporary dams, 7.—Lock, 9.—Lock gates, 11.—Dock walls, 14.—Excavations, 18.—Prices of the work, &c., 18.
——, the Campana graving, arsenal of Ferrol, Spain, 374.
Docks, Victoria, London, extension of the, referred to, 89.
Doherty, W. J., remarks as to dock and harbour works, 97.—Ditto as to the probable causes of the settlement at Avonmouth, 97.—Ditto as to the Lough Swilly reclamation embankments, 97.—Ditto as to the springs at Avonmouth being probably filtrations of the adjoining waters, 98.—Ditto as to Mr. Lyster's mode of treating similar springs at the Birkenhead Great Float, 98.—Ditto as to an important element in securing the stability of dock walls being the use of non-waterholding filling, 99.—Ditto as to machine-mixed concrete, 99.—Ditto as to Belfast harbour, 99.—Ditto as to the Hamilton graving dock and the Abercorn basin at Belfast, 100.—Ditto as to the failures at the Dufferin and Spencer docks, and their probable cause, 101.—Ditto as to Whitehaven harbour, 101.
Drainage and river improvement. *Vide* Public works.
"Draining and Improving 1,500,000 acres of Desert Land," 284.
Drawbridges, arched, on the strains produced in, by wind pressure, 345.
Dressing machinery. *Vide* Mining and metallurgy.
Duckham, F. E., remarks as to harbour and dock works, 60.—Ditto as to the danger of vessels getting jammed in locks with battering side walls, 60.—Ditto as to the silting-up of locks, 61.—Ditto as to a large dock in course of construction on the Thames with walls entirely of concrete, 61.—Ditto as to the test-load on the swing-bridge at Whitehaven, 61.
du Moncel. *Vide* Moncel.
Dumont, P., a new telephonic transmitter, 436.
Dunlop, Captain S. J., notice of the death of, 177.
Dunn, T. E., notice of the death of, 177.
Dynamo-electric machines. *Vide* Electrical science.

Eachus, G. E., remarks as to dock and harbour works, 66.—Ditto as to the design and construction of dock walls, 66.
Eads, J. B., improvement of the St. John's river, Florida, 365.
Earthworks. *Vide* Cuttings.
Eastern Canal of France. *Vide* Canal.
Edinger, W. H., admitted student, 124.
Edison, T. A., the sonorous voltameter, 438.
Electric current. *Vide* Current.
——— light, motor for, 434. *Vide* also Electrical science.
——— ——, baro-electric regulator, 435.
Electrical science. "On Progress in the Application of Electrical Science to Engineering Purposes in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78," 308.—High speed telegraphs, 308.—The telephone, 308.—Duplex signalling, 309.—Telegraph

construction, 310.—Precipitation of metals by electricity, 311.—Electric light, 311.—Dynamo-electric machines, 313.—Recent discoveries in electricity, 314.
Electro-magnet, sub-divided, 430.
Ellis, H. S., notice of the death of, 177.
Embankments for docks and harbours. *Vide* Dock, Avonmouth, *et seq.*
Emery, A. S., admitted student, 124.
Evrard's circular coal-washer, 262.
Excavators and other machines employed on the Danube regulation works, and on the canal from Gand to Terneuzen, 378.
Explosion of the flouring mills at Minneapolis, Minnesota, May 2, 1878, 407.
Explosive, a new, 439.
Explosives, properties of. *Vide* Mining and Metallurgy.

Faber, C. W., memoir of, 330.
Fabricius, H. D., admitted student, 124.
Fall River, U. S., water supply of, 386.
Feed water, purification of. *Vide* Machinery.
Ferrol, the Campana graving dock, arsenal of, 374.
Firth, G. S., admitted student, 124.
Fliegner, A., experiments on the flow of air through orifices in a thin plate, 379.
Flouring mills at Minneapolis, Minnesota, explosion of the, May 2, 1878, 407.
Flow of air. *Vide* Air.
——— water. *Vide* Water.
Flushing harbour works, the, 372.
Fly-wheels, spur, in the United States, 404.
Forrest, J., secretary, vote of thanks to, 174.
Fossombroni, Sr., his plans for the regulation of the rivers Brenta and Bacchiglione, 361.
Foundations. Excavations and foundations in sand for works on the sea coast of the department du Nord, France, 337
————, subaqueous, securing air-lock doors in sinking, by compressed air, 354.
Francis, J. B., on the cause of the maximum velocity of water flowing in open channels being below the surface, 357.
Francq, M., fireless locomotive for tramways, 399.
Freeman, J. R., notice of the death of, 177.
Frewer, C., appointed one of the scrutineers of the ballot for council, 173.—Vote of thanks to, 174.
Frizell, J. P., note on the power of running water to hold matters in suspension, 356.
Froude, W., elected member of council, 174, 206.
Fuel, utilisation of waste products for. *Vide* Machinery.
Funk, A., on the life of rails, 391.
Furnaces, blast. *Vide* Mining and metallurgy.
——— coke, experiments on the performance of, under various conditions of draught, 422.

Gaiffe, A., the electrolysis of cobalt, 438.
Galvanometer, tangent-, on a new form of, for the measurement of powerful currents, 429.
Gas, petroleum, distillation of, on the Scheuer system, 424.

Germain, P., subdivided electro-magnet, 430.
Giles, A., M.P., remarks as to harbour and dock works, 52.—Ditto as to the result of running out long piers beyond low-water mark on sandy shores, 52.—Ditto as to the Avonmouth dock, 52.—Ditto as to the best means of providing against slips in the construction of dock walls, 53.—Ditto as to the plan adopted at the Southampton docks, of removing the soil from the back of the walls, to relieve the pressure, and covering the vacant spaces by timber platforms, 54.—Ditto in explanation of his previous remarks as to the projection of solid piers from sandy shores, 64.—Elected member of council, 174, 206.
——, E., notice of the death of, 177.
Glasgow University, on the heating and ventilating apparatus of the, 124.
Glover, R. V., admitted student, 124.
Graham, J., notice of the death of, 177.
Grant, J., remarks as to the importance of sinking sumps outside the excavations for proposed docks, and at a lower level, so as to dry the ground, 67.
Graving dock, Campana. *Vide* Dock.
Gray, G. E., elected member, 124.
Green, W. H. L., the Potsdam waterworks, 383.
Griffith, J. P., remarks as to harbour and dock works, 102.—Ditto as to the contest for a closed dock or an open port at Belfast, 102.—Ditto as to the cost of the quays at Belfast, 102.—Ditto as to the causes assigned for the failure of the walls, 103.
———, Sir R., Bart., notice of the death of, 177.—Memoir of, 317.

Hall, R., notice of the death of, 177.
Harbour, Alexandria, system of short projecting jetties adopted at, instead of continuous quays, 106.
———, Belfast, "The River Lagan and Harbour of Belfast," 22.
—— ——, Boulogne. *Vide* Bergeron.
———, Flushing, works at the, 372.
———, Whitehaven. "Whitehaven Harbour and Dock Works," 36.—Natural advantages of Whitehaven as a port, 36.—Various proposals for the improvement of the harbour between 1768 and 1836, 36.—Existing dock works, 39.—Site of the new wet dock and foundations, 39.—Mode of carrying on the work, 40.—The north harbour, 40.—The Queen's dock, 42.—The dock entrance, 42.—The west quay, 43.—The gates, 44.—Facilities for traffic, 45.—Embankment and railway, 45.—The swing bridge, 46.—New timber slip, 47.—Cost of the works, 48.
——— and dock works. *Vide* also Dock, and River.
Hargrave, C. T., memorandum on roads, streets, and pavements in Victoria and Tasmania, 355.
Harkness, J. McN., notice of the death of, 177.—Memoir of, 318.
Hartley, Sir C. A., remarks as to harbour and dock works, 103.—Ditto as to the mode of construction of the quay walls of the Italian naval station of Spezia, 103.—Ditto as to the causes of the failures in the walls at Avonmouth and at Belfast, 105.—Ditto as to a mode of construction of dock walls adopted at the St. Louis Canal, mouth of the Rhone, at Marseilles, at Alexandria, and in the Hooghly at Calcutta, 105.
Hassell, L., admitted student, 124.
Hawkshaw, Sir J., Past-President, his report to the Town Council of Bristol on the various schemes proposed for improving the port, referred to, 4.—Ditto to the Belfast Harbour Trust on the improvement of the harbour of Belfast, 27.

Hawkshaw, J. C., remarks as to dock and harbour works, 66.—Ditto as to the assertion that solid piers projected from sandy foreshores tended to advance the level of low water seaward, 66.—Ditto as to the deposit of mud in such rivers as the Avon and the Humber increasing the amount of the earthwork in excavating for docks, 67.

Hayter, H., remarks as to harbour and dock works, 70.—Ditto as to the difficulties which had to be surmounted in the construction of the works at Avonmouth and at Belfast being of no ordinary kind, 70.—Ditto as to the reports of Mr. T. Page and Sir J. Hawkshaw as to docks at Avonmouth having been separate though their conclusions were the same, 71.—Ditto as to the comparative merits of iron and wooden lock gates, and his preference for the latter, 71.—Ditto as to rollers and roller paths, 72.—Ditto as to leakage round the hollow quoin, 72.—Ditto as to a form of hollow quoin used in Holland, 73.—Ditto as to the failure of the wall at Belfast, 73.—Ditto as to the comparative merits of counterforts and extended toes for ensuring the stability of dock walls, 74.—Ditto as to the success of the Whitehaven dock, 74.—Elected member of council, 174, 206.

Hearne, E. B., admitted student, 124.

Heat, radiation of, 439. *Vide* also Radiation, solar.

Heating and ventilating apparatus of the Glasgow University, 124. *Vide* Warming and ventilating.

Heinercheidt, A., securing air-lock doors in sinking by compressed air, 354.

Henin, J., slow combustion under pressure, 399.—Increased rarefaction by combination of centrifugal ventilators, 418.

Hermann, E., theory of the injector, 402.

Hess, P., a new explosive, 439.

Hétet, F., and Risbec, —, purification of greasy water by solution of lime, 400.

Higgs, P., "On Progress in the Application of Electrical Science to Engineering Purposes in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78," 308.

Higson, Jacob, elected member, 124.

Higson, John, elected member, 124.

Hofmann, Hr., Queen Carola bridge over the Elbe, near Schandau, 350.

Holker, Sir J., Q.C., M.P., opinion of, as to the privileges of Associates of the Institution, 175.

Hollingsworth, C. E., appointed one of the scrutineers of the ballot for council, 173.—Vote of thanks to, 174.

Honsell, Hr., regulation of the Rhone in the Canton of Valais, 359.

Howard quinquennial prize, Telford and Watt medals, Telford and Manby premiums, Miller scholarships and prizes, which had been awarded, were presented, 173, 192.

———————, first award of, noticed in the annual report, 180.

How, W. F., admitted student, 124.

Huddart, Capt., R.N., his report of 1804 on the improvement of Whitehaven harbour, referred to, 36.

Improvement of desert land. *Vide* Land.

Imray, J., remarks as to the heating and ventilating of Glasgow University, 156.—Ditto as to the difficulties encountered in ventilating and warming being of a "moral" rather than of a physical kind, 157.—Ditto as to the difficulty of inducing architects to make proper provision for ventilation, if likely to interfere with the beauty of their designs, 157.—Ditto as to the efficiency of

the ventilation of the temporary House of Commons, 157.—Ditto as to ventilation never getting the credit of succeeding, 158.—Ditto as to the advantages of a slight excess of pressure in a room, 158.—Ditto as to the means of breaking up and diffusing the currents of air, 159.—Ditto as to the futility of high-level inlets, 159.—Ditto as to the fair measure of success attained at Glasgow, 160.
Injector, theory of the, 402.
———, the Korting, as an air blast, 403.
Iron, use of, in securing underground workings. *Vide* Mining and metallurgy.

Jackson, R. G., admitted student, 124.
Jeffrey, R., notice of the death of, 177.
Jetties, South Pass, Mississippi river, the, 367.
Johnson, J. W., transferred member, 124.
Jones, Major H. H., R.E., on the construction of the Narora works, head of the Lower Ganges canal, 371.

Käferstein H., substitution of a single span for two openings of the Magdeburg railway bridge, 352.
Kay, G., admitted student, 124.
Keating, E. H., transferred member, 124.
Keller, K., on the calculation of pitch chains, 406.
Kelly, W. R., remarks as to harbour and dock works, 106.—Ditto as to the causes of the failure of the walls of the Spencer and Dufferin docks, Belfast, 106.—Ditto as to the best means of dealing with a foundation subsoil similar to that encountered at Belfast, 107.
Kew Gardens, hot-water boilers at, 168.
Knorpp, C. B., transferred member, 124.
Kohfahl, R., on the strains produced in arched drawbridges by wind pressure, 345.
Könyves-Tóth hand rock-drill, 414.
Korting injector, the, as an air blast, 403.

Laduron, G., casting of chilled gearing for roll trains, 405.
Lancaster, C. W., notice of the death of, 177.
Land. "Draining and Improving 1,500,000 acres of Desert Land," 234.—Description of the former state of the "Landes" of Gascony, 234.—Failure of the early attempts at improvement, 235.—Report of M. Chambrelent in 1849, 235.—Experimental trial of 1,250 acres, 236.—Law of 1857 decreeing the drainage of the Landes, 237.—Construction of 1,365 miles of drainage canals, 238.—Cultivation of forest trees on the reclaimed land, 238.—Indirect benefits resulting from the drainage of the land, 239.—Maintenance of the main canals, 240.
"Landes" of Gascony. *Vide* Land.
Laroche, M. *Vide* Stoecklin.
Latimer, J., admitted student, 124.
Law, H., appointed one of the scrutineers of the ballot for council, 173.—Vote of thanks to, 174.
Lean, J., notice of the death of, 177.
Lefebvre, R., on the nature of soils, and on slips in clay soils, 338.
Libert, J., self-lubricating hollow axle for mining wagons, &c., 398.
Lighthouse, Ar-men, 285.
Locks and lock-gates, different types of construction of, 9 *et seq.*
Locomotive, fireless, for tramways, 399.

Locomotives, foreign. *Vide* Machinery.
Lovell, T., notice of the death of, 177.
Lyster, G. F., remarks as to one of the graving docks off the Great Float at Birkenhead docks, 120.

Machinery. "On the Progress of Machinery in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78," 286.—Steam engineering, 286.—Comparative performance of single and compound cylinders in marine engines, 288.—Mechanical equivalent of heat, 289.—Evaporative performance of steam boilers, 290.—Utilisation of waste products as fuel, 291.—Corrosion and incrustation of boilers, 292.—Purification of feed-water, 293.—Locomotive engines, 293.—Warming railway carriages, 295.—Water motors, 295.
Mackenzie, J. B., "The Avonmouth Dock," 3.—Remarks as to the cost of the works of ditto, 64.—Ditto as to the lime concrete used in the foundation of the dock, 90.—Ditto as to the large sectional area of the sluicing ways in the lock, 90.—Ditto as to the lock-gate rollers, 90.—Ditto as to the predicted ill effects of the tidal ebb and flow not having occurred, 90.—Ditto as to dockizing the Avon, 91.—Ditto as to the walls of the Avonmouth dock, 91.—Ditto as to the sufficiency of the formula, "$t=pr$", when applied to the dock gates at Avonmouth, 93.—Ditto as to his preference for timber gates, 93.—Ditto as to the cost of the ashlar, 94.—Ditto as to vertical or battered faces for lock walls, 94.—Ditto as to the hydraulic machinery at Avonmouth, 94.—Ditto as to the springs not being due to filtration from the river, 114.—Ditto as to the temporary clay dam, 114.—Ditto as to the paddle frames, 114.—Ditto as to the "danger of a blow under the sill" being imaginary, 115.—Ditto as to the unadjustable roller, 115.—Ditto as to the overhang of the gates, 115.—Ditto as to the statement, that there was no provision for a caisson at the upper end of the lock, being incorrect, 116.—Ditto as to the *teredo navalis* not existing in the Bristol Channel, 116.—Ditto as to the relative economy of iron and timber gates, 116.—Ditto as to the rule for fixing the positions of the rollers, 117.—Ditto as to the mode of depositing the backing, 117.—Ditto as to the quantity and price of iron in the dock gates, 118.—Ditto as to the cost of the works being moderate, 117.
Mackinnon, W. MacL., admitted student, 124.
MacLaren, B. L., admitted student, 124.
McMaster, B., notice of the death of, 177.
Macnab, A., elected member, 124.
Macneill, Sir J., his proposed breakwater at Portishead, referred to, 4.
Magnetic meridian. *Vide* Meridian.
Magneto-electric machines, experimental researches on, 430. *Vide* also Electrical science.
Manby and Telford premiums, Telford and Watt medals, Miller scholarships and prizes, and Howard quinquennial prize, which had been awarded, were presented, 173, 192.—List of subjects for, session 1878–79, 194.
Manby, C., honorary secretary, vote of thanks to, 174.
Manchester Free Trade Hall, and Manchester Royal Exchange, ventilation of, referred to, 149.
Marine engines, comparative performance of compound and single cylinders. *Vide* Machinery.
Marsaut, J. B. "Coal-Washing Apparatus at Bessèges, France." Translated and abstracted by A. Bache, 259.

Martin, S. D., notice of the death of, 177.
Martindale, Col. B. H., C.B., remarks as to harbour and dock works, 89.—Ditto as to the extension of the Victoria Docks, London, 89.—Ditto in dissent from the assertion that docks for ocean-going steamers should now be 600 feet wide, 89.—Ditto as to the width of the Victoria Dock Company's new dock, 89.
Mascart, M., and Angot, M., experimental researches on magneto-electric machines, 430.
Mativa, H., air-compressors and rock-boring machines, 411.
May, R. C., appointed one of the scrutineers of the ballot for council, 173.—Vote of thanks to, 174.
Mechanical equivalent of heat. *Vide* Machinery.
Medals, Telford and Watt, Telford and Manby premiums, Miller scholarships and prizes, and Howard quinquennial prize, which had been awarded, were presented, 173, 192.—List of subjects for, session 1878–79, 194.
Memoirs of deceased members, 315.
Meridian, magnetic, application of the telephone to the determination of the, 435.
Mersanne, M. de, motor for electric lamps, 434.
Metallurgy. "On the Progress of Mining and Metallurgy in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78," 297.
Metcalfe, C. P., admitted student, 124.
Microphone, the physical action of the, 437.
Miller fund, referred to in the annual report, 185.
—— scholarships and prizes, Telford and Watt medals, Telford and Manby premiums, and Howard quinquennial prize, which had been awarded, were presented, 173, 192.—List of subjects for, session 1878–79, 194.
Mills, flouring, at Minneapolis, Minnesota, explosion of the, May 2, 1878, 407.
Mine ventilators. *Vide* Ventilators.
Mineral produce of Austria in 1877, 426.
—— —— Russia in 1876, 427.
Mining and metallurgy. "On the Progress of Mining and Metallurgy in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78," 297.—Machine boring, 297.—Explosives, 299.—Machine cutting, 299.—New deep winnings, 300.—Pumping machinery, 301.—Use of iron for underground workings, 303.—Dressing of minerals, 303.—Metallurgy, 305.—Blast furnaces, 305.—Converting furnaces, 305.—Bessemer plant, 306.—Metallurgy of precious metals, 306.
Moncel, Count du, variations in the strength of electric currents transmitted through imperfect conductors under variation of pressure exerted upon them, 428.—On some new effects produced in the telephone, 436.—The physical action of the microphone, 437.
Moody, A., admitted student, 124.
Morin, Gen. A., his system of ventilation referred to, 124 *et seq.*
Mortimer, J. R. "The Chalk Water Supply of Yorkshire," 252.
Müller, F. C. G., researches on the German Bessemer process, 419.
Mylne, W. C., his proposed masonry pier at Portishead, referred to, 4.

Nelson, T. B., notice of the death of, 177.
Norris, R. S., notice of the death of, 177.

Obach, E., on a new form of tangent galvanometer for the measurement of powerful currents, 429.

Original communications, list of subjects for, session 1878–79, 194.—Instructions as to preparing ditto, 197.

Page, T., his report to the Town Council of Bristol on various schemes proposed for improving the port, referred to, 4.
Paleocapa, Sr., his plans for the regulation of the rivers Brenta and Bacchiglione, 361.
Parker, S. H., admitted student, 124.
Parkes, W., remarks as to harbour and dock works, 61.—Ditto as to the evils that might be expected to result from dockizing the Avon, 62.—Ditto as to there being many cases where the projection of piers from a sandy shore would not necessarily result in the advancement of the low-water line seaward, 62.—Ditto as to the breakwater at Port Saïd, 63.—Ditto as to the causes which led to the silting up of Whitehaven harbour, 63.
Parville, H. de, the application of the telephone to the determination of the magnetic meridian, 435.
Patterson, W. W. *Vide* Rendel, J. M.
Pavements, memorandum on, in Victoria and Tasmania, 355.
Peckham, S. F., explosion of the flouring mills at Minneapolis, Minnesota, May 2, 1878, 407.
Penn, J., notice of the death of, 177.
Penny, A., jun., elected member, 124.
Perron, E., theory of the action of railway brakes, 394.
Petroleum gas. *Vide* Gas.
Phipson, W. W., "On the Heating and Ventilating Apparatus of the Glasgow University," 124.—Remarks as to ditto, 169.—Ditto as to the defects indicated in the discussion being now in process of amendment, 169.—Ditto as to the Free Trade Hall and the Royal Exchange, Manchester, not being apposite examples from which to criticise the cost of the works at Glasgow, 170.—Ditto as to the expenditure of coal, 170.—Ditto as to the temperature of the class-rooms, 170.—Ditto as to the ventilation of the Trocadero Palace at Paris, confirming his preference for the screw fan, 171.
Piccard's apparatus for evaporating brine without fuel, 408.
Piling machines. *Vide* Public works.
Pitch chains, on the calculation of, 406.
Plocq, M., excavations and foundations in sand for works on the sea coast of the department du Nord, France, 337.
Ploix, E., his hydrographic survey of the shore near Boulogne, referred to, 79 *et seq.*
Poirée's needle dam, on the Eastern canal of France, described, 230
Pole, W., elected member of council, 174, 206.
Ponti, G., the regulation of the rivers Brenta and Bacchiglione, according to the plans of the engineers Fossombroni and Paleocapa, 361.
Pooley, H., notice of the death of, 177.—Memoir of, 331.
Port of Belfast. *Vide* River Lagan.
——— Bristol. *Vide* Dock, Avonmouth.
——— Whitehaven. *Vide* Harbour, Whitehaven.
Portland cement. *Vide* Cement.
Potsdam waterworks, the, 383.
Premiums, Telford and Manby, Telford and Watt medals, Miller scholarships and prizes, and Howard quinquennial prize, which had been awarded, were presented, 173, 192.—List of subjects for, session 1878–79, 194.

Public works. "On the Progress of Public Works Engineering in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874–78," 275.—Bridges of iron and of steel, 275.—Secondary railways, 276.—Progress of the metre gauge, 277.—Systems for surmounting steep gradients, 278.—Tramways, 279.—Steam carriages, 280.—Continuous brakes, 280.—Piling machines, 280.—Sewerage works, 281.—Dams, 282.—Water supply, 282.—Drainage and river improvement, 283.—Fluviometrical observations, 284.—Ar-men lighthouse, 285.
Publications of the Institution referred to in the annual report, 179.
Pumping machinery. *Vide* Mining and metallurgy.
Purdon, H. A., admitted student, 124.
Purification of greasy water by solution of lime, 400.

Quebec waterworks, the, 387.

Radiation of heat, 439.
———, solar, 438.
Radinger, J. F., spur fly-wheels in the United States, 404.
Rails, on the life of, 391.
Railway brakes, theory of the action of, 394.
——— ———, continuous, 396.
——— carriages, warming. *Vide* Machinery.
———, Lima and Oroya, 387.
——— rolling stock, on double-hook couplings, as replacing safety chains for, 393.
Railways, secondary, conditions for the establishment of, 388. *Vide* also Public works.
Rappersweil, Zurich, lake dam at, 376.
Rawlinson, R., C.B., elected member of council, 174, 206.
Receipts and expenditure, abstract of, from the 1st of December, 1877, to the 30th of November, 1878, 188. *Vide* also Report.
Receiving instrument for submarine lines, 428.
Reclamation of desert land. *Vide* Land.
Redman, J. B., remarks as to harbour and dock works, 59.—Ditto as to the amount of tidal oscillation materially affecting the difficulty of construction and the proportionate cost of harbour works, 59.—Ditto as to his preference for improvements by dredging channels in a tidal river rather than by attempting to canalize its port, 60.—Ditto (foot note) extracts from reports relative to Dover and Folkestone harbours, 60.
Rees, J. R., elected member, 124.
Regulator, baro-electric light, 435.
Reid, Dr., his system of ventilation referred to, 152.
Rendel, J. M., his report of 1860 on the improvement of Whitehaven harbour, referred to, 39.
———, Patterson, W. W., and Thornton, G., their proposal for an ocean steam-packet station at the mouth of the Avon, referred to, 4.
Rennie, J., his reports on the improvement of Belfast harbour (1821), referred to, 24.—Ditto ditto Whitehaven harbour (1804), 36.
———, Sir J., his report of 1853 on the improvement of Whitehaven harbour, referred to, 37.
Report, annual, read and ordered to be printed, 173.—Constitution of the society, 175.—Elections and transfers, 176.—Tabular statement for the years 1876–77,

and 1877-78, of transfers, elections, deceases, resignations, and erasures of members of all classes belonging to the Institution, 176.—Deaths announced during the year, 177.—Resignations, 178.—Admission of students, 178.—Contributions to the funds, 178.—Balloting list for council, 179.—Meetings and publications, 179.—First award of the Howard quinquennial prize, 180.—Progress reports on engineering abroad, 181.—General index to the "Minutes of Proceedings," volumes I. to L., 181.—Supplemental meetings for students, 181.—Meetings of other societies, 182.—Paris Exhibition of 1878, 183.—The library, 183.—The property of the Institution, 184.—Question of the liability of the Institution for local rates and taxes, 185.—Value of the funded property, 186.—Abstract of receipts and expenditure, 188.—Premiums awarded, session 1877-78, 192.—Subjects for papers, session 1878-79, 194.—Instructions as to preparing ditto, 197.

Resignations of members and associates, list of, 178.

Reynolds, R., transferred member, 124.

Risbec. *Vide* Hétet.

Rittinger, Hr., theoretical investigations of, as to coal-washing apparatus, 259.

River Avon. *Vide* Dock, Avonmouth.

—— Bacchiglione. *Vide* Brenta.

—— Brenta. The regulation of the rivers Brenta and Bacchiglione, according to the plans of the engineers Fossombroni and Paleocapa, 361.

—— Danube regulation works, pile drawers employed on the, 379.

—— Elbe, observations on the level of the, in Saxony, 358.

—— Hooghly, screw-pile jetties adopted in the, at Calcutta, 106.

—— Lagan. "The River Lagan and Harbour of Belfast," 22.—General description of the river Lagan, and of the docks, quays, &c., constituting the harbour, 22.—Recommendations of the Messrs. Rennie, Mr. Telford, and Mr. Rhodes, for the improvement of the harbour, 24.—Report of Messrs. Walker and Burges, 24.—Commencement of the improvement works in 1858, 26.—Measures proposed by Messrs. Bell and Miller, and by Sir John Hawkshaw, 27.—Table of dimensions of the various docks and quays at the port of Belfast, 29.—Ditto of the graving docks, 30.—Settlements of the walls of the Dufferin and Spencer docks, 32.—Reconstruction of the Spencer tidal dock, 33.—Timber wharf on Queen's quay, 34.—Reconstruction of the Albert quay, 35.—Diagram of the trade of the port of Belfast from 1786 to 1876, 35.

—— Mississippi, South Pass jetties of the, 367.

—— Rhone, regulation of the, in the Canton of Valais, 359.

——, St. John's, Florida, improvement of the, 365.

Rivers, improvement of. *Vide* Public Works.

Rivers, E. G., remarks as to the heating and ventilating of Glasgow University, 168.—Ditto as to the hot-water boilers used at the Royal Gardens, Kew, 168.

Roads, streets, and pavements in Victoria and Tasmania, memorandum on, 355.

Rock-boring machines and air-compressors, 411.

—— drill, the Könyves-Tóth hand rock-drill, 414.

Rolling mills, casting of chilled gearing for roll trains, 405.

Rottmüller, A. *Vide* Schnorr v. Carolsfeld.

Round Down cliff, Dover, effect of the removal of, on the travel of the shingle east of Folkestone, 84, 88.

Rumball, A., appointed one of the auditors of accounts, 173.—Vote of thanks to, 174.

Russ, W., elected member, 124,

Russia, mineral produce of, in 1876, 427.

Salmond, T. R. "The River Lagan and the Harbour of Belfast," 22.—Remarks as to ditto, 118.—Ditto as to the relative cost of the construction of the Queen's quay and the Albert quay, 118.—Ditto as to the objections to the construction of a permanent stone structure, 119.—Ditto as to the methods which had been proposed by Sir John Hawkshaw for securing the walls of the Dufferin and Spencer docks, 119.—Ditto as to the suddenness of the collapse of the Spencer dock entrance wall, 119.

Scheuer system for the distillation of petroleum gas, 424.

Scheurer-Kestner, A., the Korting injector as an air blast, 403.

Schmidt, M. W., observations on the level of the Elbe in Saxony, 358.

Schneider, C., on continuous brakes, 396.

Schnorr v. Carolsfeld, C., and Rottmüller, A., iron bridge over the river Inn at Königswart, near Wasserburg, 347.

Schönheyder, W., remarks as to the heating and ventilating of Glasgow University, 166.—Ditto as to the advantages that would accrue from reversing the inlets in winter and in summer, 166.—Ditto as to there being no absolute rule in favour of upward or of downward ventilation, 166.—Ditto as to the Galton stove as a ventilator, 166.—Ditto as to the advantages of pressure in a room, 166.—Ditto as to a simple arrangement of valves whereby air-channels might be used either for supplying or withdrawing the air, 167.—Ditto as to the wastefulness of the screw ventilator, 167.—Ditto as to the friction of the air-channels, 167.

Schulze, C. W., employment of an iron caisson for sinking under a solid shafthead at Grosstadeln, near Leipzig, 414.

Scott, G. W. D., admitted student, 124.

Seefehlner, J., on the determination of the stresses permissible in structures, 342.

Sewerage works. *Vide* Public works.

Shaft-sinking, employment of an iron caisson for sinking under a solid shaft-head at Grosstadeln, near Leipzig, 414.

Shellshear, W., admitted student, 124.

Sherriff, A. C., M.P., notice of the death of, 177.

Shirley, L. H., transferred member, 124.

Shoolbred, J. N., remarks as to the heating and ventilating of Glasgow University, 161.—Ditto as to the various considerations presenting themselves in any scheme of practical ventilation, 161.—Ditto as to the questionable success of downward ventilation at Glasgow, 161.—Ditto as to effects of high-level inlets, as shown by Professor James Thomson's experiments, 162.—Ditto as to the ventilation of the Conservatoire des Arts et Métiers, Paris, 162.—Ditto as to the allowance of 750 cubic feet of air per person per hour being too little, especially at night, 162.—Ditto as to placing pipes over the gas jets to carry away the products of combustion, 163.—Ditto as to the ventilation of the meeting room of the Institution, 164.—Ditto as to the advantage of the electric light in not burning the air, 164.—Ditto as to elevated intakes not always ensuring purity of the air, 164.—Ditto as to the downward ventilation at the Trocadero Palace, Paris, 165.

Siemens, C. W., elected member of council, 174, 206.

Skrine, W, D., admitted student, 124.

Slips. On the nature of soils, and on slips in clay soils, 338.

Smeaton, J., his proposal of 1768 for the enlargement of Whitehaven harbour, referred to, 36.

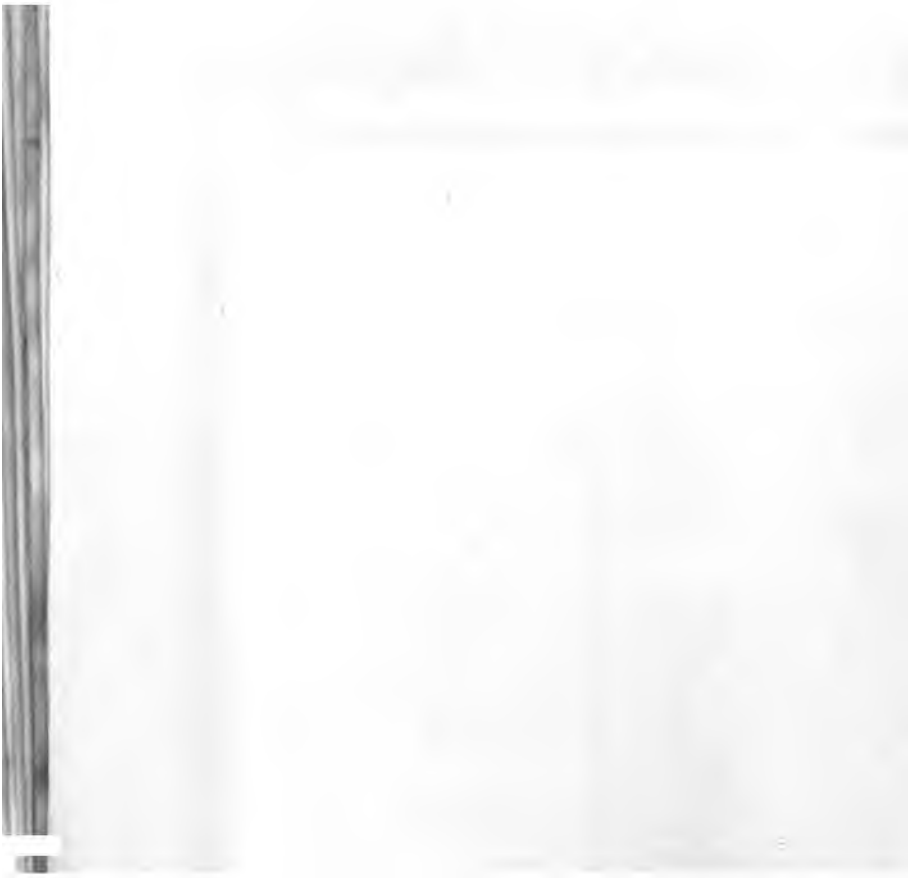
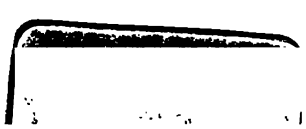
Smith, C. G., remarks as to dock and harbour works, 64.—Ditto as to the shape of the dock entrance at Avonmouth contrasted with that adopted at Liverpool,

64.—Ditto as to concrete-mixing machines, 65.—Ditto as to the difference between the inclinations in the bases of dock and of railway walls, 166.
———, T. M., appointed one of the scrutineers of the ballot for council, 173.—Vote of thanks to, 174.
———, W., notice of the death of, 177.
Soils, on the nature of, and on slips in clay soils, 338.
Solar radiation, 438.
Special general meeting of corporate members for the purpose of enacting certain new bye-laws and regulations, and of altering and repealing certain existing ones, November 5, 1878, 1.—Ditto December 2, 1878, 121.
Spur fly-wheels in the United States, 404.
Stanley, W., remarks as to harbour and dock works, 107.—Ditto as to the rise of the equinoctial spring tides at Avonmouth, 108.—Ditto as to the mode of dealing with the springs encountered in the bottom of the dock, 108.—Ditto as to the paddle frames, 108.—Ditto as to the settlement of the recess and the rising of the outer platform, 108.—Ditto as to the roller path of the gates, 109.—Ditto as to the material and construction adopted for the gates, 109.—Ditto as to the additional roller, 110.—Ditto as to the 100-feet gates at Liverpool, 110.—Ditto as to the failure of the west wall at the Avonmouth dock, 110.—Ditto as to the generally unsuccessful nature of the operations at Avonmouth, 111.—Ditto as to Belfast harbour, 111.—Ditto as to the bad nature of the backing having probably caused the failure, 111.—Ditto as to the Whitehaven harbour works, 112.
Steam-carriages. *Vide* Public works.
Steel, Bessemer. *Vide* Bessemer process.
Stephen, Sir F., Q.C., opinion of, as to the privileges of Associates of the Institution, 175.
Stevenson, D., elected member of council, 174, 206.
Stoecklin and Laroche, MM., extracts from a report by, as to the improvement of the port of Boulogne, 75.—Position of Boulogne, at the bottom of a secondary inlet, presenting an additional complication in any solution of the problem of harbour accommodation, 75.—Geological constitution of the soil between Bourg d'Ault and Cape Alpreck, 75.—Tidal economy of that part of the Channel near Boulogne, 78.—Hydrographic survey made in 1876 by M. E. Ploix, 79.—Character of any new works determined by considerations which practically reduced the alternative plans to two, 80.—Plan of an open roadstead formed by an isolated breakwater, 81.—Current between the Bassure de Baas and the shore, 81.—Deep-water port as sanctioned, and answer to objections against it, 83.—Mode of construction decided upon, 83.
Stokes, F. W. S., admitted student, 124.
Stoney, B. B., remarks as to harbour and dock works, 112.—Ditto as to the doubtful expediency of using wood for the gates of the Avonmouth dock, 113.—Ditto as to the 70-feet iron gates of the Dublin graving dock, 113.—Ditto as to roller paths, 113.—Ditto as to the increasing length of ocean steamers, 113.
Stresses, on the determination of the, permissible in structures, 342.
Struvé, W. P., notice of the death of, 177.
Stubbs, W. H., elected member, 124.
Subjects for papers, session 1878–79, 194.
Sutcliffe, —, description of his concrete-mixing machine, used at the North docks Liverpool, 65.
Swetenham, Major G., R.E., notice of the death of, 177.—Memoir of, 334.
Swinburn, J., elected member, 124.

Tangent-galvanometer. *Vide* Galvanometer.
Telegraph, receiving instrument for submarine lines, 428.
Telegraphic transmission. *Vide* Electrical science.
Telephone, the. *Vide* Electrical science.
————, application of the, to the determination of the magnetic meridian, 435.
————, on some new effects produced in the, 436.
Telephonic transmitter, a new, 436.
Telford and Watt medals, Telford and Manby premiums, Miller scholarships and prizes, and Howard quinquennial prize, which had been awarded, were presented, 173, 192.—List of subjects for, session 1878–79, 194.
Testing machines for iron and steel, 408.
Thomson, Dr. A., remarks as to the heating and ventilating of Glasgow University, 147.—Ditto as to the system having suffered from not having been matured until the whole plans of the building and drainage had been decided upon, 148.—Ditto as to his experience being that the results were generally satisfactory, 148.—Ditto as to his preference for coils of hot-water pipes within the rooms instead of the introduction of heated air in large bodies from without, 149.—Ditto as to the dimensions of the Glasgow University buildings, 151.
————, Prof. James, remarks as to the heating and ventilating of Glasgow University, 144.—Ditto as to the works carried out being only moderately successful, 144.—Ditto as to the evils resulting from the abandonment of the recommendation to supply cold fresh air with the hot fresh air, 144.—Ditto as to the size of the air passages, 145.—Ditto as to high-level *versus* low-level admission, 145.—Ditto as to the objectionable feature of the air being conveyed through underground channels, 146.—Ditto as to the problem of effectually warming and ventilating a set of buildings like the Glasgow University being not yet solved, 147.
————, John, appointed one of the scrutineers of the ballot for council, 173.—Vote of thanks to, 174.
Thorburn, W., admitted student, 124.
Thornton, G., his various designs for piers and docks for the port of Bristol, also for "dockizing" the Avon, referred to, 4.
Thornycroft, J. I., remarks as to the heating and ventilating of Glasgow University, 160.—Ditto as to the advantages of having a slight excess of pressure within the building, 160.—Ditto as to the apparent reasons for adopting a high-level inlet, 160.—Ditto as to a system of ventilation in which the air passages would be superseded by large corridors branching to the various parts of the building, 160.
Thorold, W., memoir of, 321.
Tides of the Bristol Channel at Avonmouth, range of the, 6.
Tolkmitt, G., determination of the thickness and form of the arches of stone bridges, 344.
Tolmé, J. H., memoir of, 319.
Topham, F. D., admitted student, 124.
Torrents on the coast of the Ionian Sea between Reggio and Assi, in the province of Calabria Ultra, 364.
Toulmin, E. H., admitted student, 124.
Tracings, note on the so-called blue process for copying, 443.
Tramway locomotive, fireless, 399.
Tramways. *Vide* Public works.
Transmitter, telephonic, a new, 436.

Trève, M., on the variation of current under modification of pressure contact, 429.
Trocadero Palace, Paris, ventilation of the, 165.
Tulk, H., admitted student, 124.

University of Glasgow, heating and ventilating apparatus of the, 124.

Ventilating apparatus, heating and, of the Glasgow University, 124.
Ventilation of the transport steam ship "Annamite," 441.
Ventilators, centrifugal, increased rarefaction from combination of, 418.
Verein von Gas und Wasserfachmännern Deutschlands, experiments on the performance of coke furnaces under various conditions of draught, made by a commission appointed by the, 422.
Verity, B., remarks as to the heating and ventilating of Glasgow University, 171.—Ditto as to a ventilating machine devised by him, 171.—Ditto as to his system being adopted at the Reform Club, 172.
Vernon-Harcourt, L. F., "On the Progress of Public Works Engineering in Foreign Countries, as recorded in the Abstracts of Papers in the Proceedings, during the years 1874-78," 275.
Villari, Sr., radiation of heat, 439.
Voltameter, the sonorous, 438.

Waddington, R., admitted student, 124.
Warming and ventilating. "On the Heating and Ventilating Apparatus of the Glasgow University," 124.—The atmosphere not exempted from obeying the laws of gravitation, 125.—Conclusions of the sub-committee of professors appointed in 1864 to consider the general principles upon which the ventilation and warming of the new University should be carried out, 125.—Volume of cubic feet of air per hour per sitting governing the dimensions of the air passages, 126.—Advantages of high-level over low-level distribution, 128.—Flues, 129.—Power required to drive ventilation fans, 129.—Extraction shafts, 130.—Heating surface of the pipes, 133.—Proper form of boiler for ventilation purposes, 134.—General description of the mechanical apparatus used at Glasgow, 135.—Experiments to ascertain the amount of air delivered by the fan, 138.—Fuel consumed in working, 141.—Cost of the works, 141.—APPENDIX: Glasgow University: average monthly temperatures at 8 a.m.; sessions 1871-72 and 1872-73, 142.
Water, flow of, in pipes under pressure, 381.
——, ——, in open channels, cause of the maximum velocity of, being below the surface, 357.
—— motors. *Vide* Machinery.
——, purification of greasy, by solution of lime, 400.
——, running, note on the power of to hold matters in suspension, 356.—Cause of the maximum velocity of water flowing in open channels being below the surface, 357.
—— supply. "The Chalk Water Supply of Yorkshire," 252.—Distribution of the chalk deposits in Yorkshire, 252.—Irregularities of the subterranean waterline in the chalk formation, 253.—Average annual rainfall on the Chalk Wolds, 254.—Conditions which govern the flow of the "Wold gypsey races," 254.—Permanent and intermittent springs along the base of the outer margin of the chalk, 256.—Inexhaustible amount of the chalk water supply in Yorkshire, 258.
—— works. *Vide* also Public works.